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ORIGINAL STUDIES

Dietary aspects related to height growth rate and the risk of malnutrition in children

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Abstract
Background. Malnutrition in children is bound to an imbalanced food intake. A negative energy intake can lead to improper anthropometric changes.
Aims. The aim of the study is to analyze the protein intake and the main food groups in preschool children to identify the possible food-related causes that favor changes in the weight and/or height-growing rate.
Methods. The study protocol included a transversal and observational assessment held between March and September 2019. The sample comprised 207 subjects, which were divided into two groups depending on their anthropometric development and the BMI for age Z score. Daily food intake was assessed by using an accurate feeding log obtained from the subjects' legal guardian.
Results. A reduced protein intake was associated with a def cient body height growth, as seen in both G1 (p=0.048, r=0.254) and G2 study samples (p=0.004, r=0.399). In the underweight sample (G2), protein intake was related to age (p=0.024, r=0.317), body weight (p=0.001, r=0.452) and the consumption of fruit juice (p=0.001, r=-0.428). The changes in body mass index were related to the meat food products in the normal weight subjects (p=0.040, r=0.187) and to the cereal products in the underweight subjects (p=0.0007, r=-0.385).
Conclusions. The lack of protein intake is associated with changes in anthropometry development, especially with a drop in the height growth rate.
Keywords: height growth rate, malnutrition, food intake, protein

Introduction

Malnutrition in children is bound to an imbalanced food intake. A negative energy intake alongside the lack of several nutrients can lead to improper anthropometric changes, of which the most important is described as *weak development of the muscle tissue* (Cederholm et al., 2017). Even though such changes are often seen in adult patients, similar cases are also seen in young age patients. Therefore, various papers describe an increased risk of related pathologies (Rytter et al., 2014; Ibrahim et al., 2017), by stating important changes in the growing up rate, which can af ect long-term height and body weight development (Rytter et al., 2017). By using similar based measurements, several papers described malnutrition as being a leading risk factor for various medical conditions. Based on the current statistical data, malnutrition is underdiagnosed; the real impact that malnutrition has upon the risk of developing a disease is therefore insuf ciently known.

Clinical evaluation alongside anthropometric measurements can be used to assess the nutritional status of individuals regardless of age and condition. Various papers cited the need for implementing constant monitoring systems for the early identif cation of individuals and communities that require interventions. Such actions are important in order to limit the nutritional def cit and to rebalance the physical development in risk related groups (Corkins, 2017). The assessment of the child that suf ers from malnutrition, along with the treatment intervention

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and the prevention protocol should be carried out in a multidisciplinary manner (Bouma, 2017); therefore, age-adapted medical, diet-related and psychological consult is important during early age.

As seen in the paper of Alasfoor et al. (2007), the physical maternal and child prenatal characteristics can strongly inf uence individual anthropometric development. Yet, other factors can be included: economic, dietary and socio-environmental factors are used to assess the risk of malnutrition. According to Jackson et al. (2006), the main consequence of malnutrition refers to the survival condition due to improper anthropometric development, while on the other hand, more children are consuming energy-dense and nutrient-poor food products. Excessive energy intake can decrease resting energy expenditure in time due to less active tissue, which can easily cause excessive energy intake (Müller & Geisler, 2017).

Each of the two eating patterns can negatively af ect long-term anthropometric development. Over time, few papers have studied the dif erences regarding daily energy intake in underweight, normal weight and overweight study groups, while taking into account all factors that can inf uence each of the conditions. It is generally known that protein intake is related to anthropometric development. Yet, less data is available regarding fat and carbohydrates in underweight study groups, while more data is illustrated for obesity, mainly under excessive carbohydrate, protein and fat intake.

Numerous papers have studied eating patterns and medical related conditions. Of them, various results are related to anthropometric development according to age, while less data is related to daily food intake. Therefore, the study aim is to analyze protein intake and the main food groups in preschool children to identify the possible food-related causes that favor changes in the weight and/or height-growing rate.

Material and methods

Research protocol

A transversal and observational study was conducted on a group of 207 healthy children.

a) Period and place of the research

The study was conducted between March and September 2019 in Mureș county, Romania.

b) Subjects and groups

The study sample was composed of 207 subjects. The study sample was divided into two groups (n=2) depending on their anthropometric development and the BMI for age Z score. Therefore, the normal weight group (G1) included 133 subjects (64.25%), which had a Z score higher than -2 and lower than +2. The underweight study group (G2) included 74 subjects (35.74%) which had a Z score lower than -2.

The following criteria were used for inclusion in the study: age between 36 and 84 months old, clinically healthy children with no history of acute diseases in the past 6 months, normal weight at birth, due time delivery, legal guardians willing to collect data regarding daily food intake. Exclusion criteria: age outside the range of interest, lack of compliance for determining weight and height, presence of any chronic or acute pathology diagnosed during the collection of anthropometric and food-related data, consumption of food supplements or medicines, including medically prescribed products.

c) Applied tests

Anthropometric development assessment

To assess physical development, we determined the individuals' body weight and body height; according to the results, the body mass index and the BMI for age Z score were subsequently calculated by using both age and gender related information. Weight was measured in the morning, after a feeding rest of at least 8 hours, in an upright position, in casual clothes, by means of a calibrated standard scale (ADE GmbH, Germany). The measurements were repeated 3 times in a row, at 30-second intervals, with the exclusion of any aberrant data; statistical analysis used the average of the 3 measures carried out. The height of the subjects was established in upright position, shoes of , by means of a standard wall height meter (ADE GmbH, Germany). During each measurement, the subjects were instructed to stay still, eyes straight ahead, upper limbs along the body, lower limbs brought together while normally breathing.

The body mass index (BMI) was determined by using the weight to the height data, according to the standard calculation formula W/H^2. BMI was interpreted by entering the values obtained, along with the child's age (expressed in months) and gender, into the *Anthro Survey Analyzer* (WHO) software. The Z score was calculated automatically by using the above-mentioned software.

All data was interpreted in the following way: the subjects whose score was less than -2 were included in the underweight group (G2) and those who scored more than -2, but less than +2, were included in the normal weight group (G1). The children whose Z score was higher than +2 were deemed to have an excessive weight and were excluded from the study group.

Eating scheme assessment

Daily food intake was assessed by using means of an accurate feeding log obtained from the subjects' legal guardians who were instructed to put down the food items eaten by the child, jointly with their quantity. The subjects whose logs did not contain the grams corresponding to the products consumed were excluded from the study group. In the food log, the individuals wrote down the consumed products, not the of ered ones, which enabled the subsequent calculation of protein ingestion over a 24-hour period. The nutritional value of each food product was calculated by using means of the accredited food composition tables provided by the *USDA's Food Composition Databases*, a property of the United States' Department of Agriculture (2019).

d) Statistical processing

Statistical evaluation was carried out with the GraphPad Prism 6.0 software, with a level of signif cance set at α=0.05. The tests used for the inferential assessment were: Mann Whitney test for the dif erences between the two study groups and the Spearman r test for assessing the relation between two analyzed parameters. The data were presented by using descriptive data as the median value, the minimum-maximum values and the coef cient of variation (CV). Due to food intake variability, the average values were not used in this study.

Results

Anthropometric data

The normal weight sample (G1) had a median age of 39 months, with the CV reaching 27.91%. The underweight sample (G2) had a median age of 38 months, with the CV reaching 14.07%. There were no considerable dif erences between the age of the two study groups (p = 0.1112).

The body weight reached a median value of 12 kg (Min-Max: 10-15 kg; CV = 21.51%) in G2 and 14 kg (Min-Max: 8-28 kg; CV = 12.79%) in G1. Further data regarding the body height and the individuals' body mass index are comparatively analyzed in Table I and Fig 1.

Important dif erences are observed regarding the BMI value between the two groups (p < 0.05); yet, no dif erences in the body height values are seen (> 0.05).

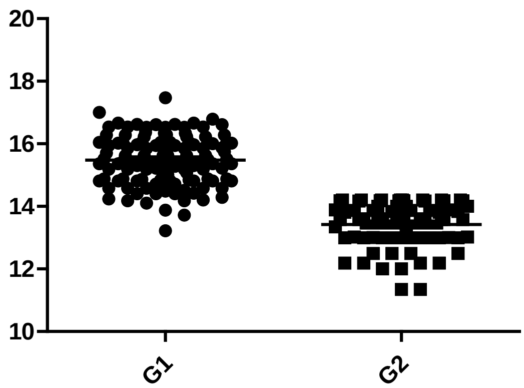

Fig. 1 – Body mass index - dif erences between the groups.

Eating frequency data

The daily water intake reached 500 ml/day in G2 study group, with a 53.62% CV, and 600 ml in G1, with a 46.17% calculated CV. Furthermore, a median intake of 250 ml milk was monitored in G1 and 275 ml in G2, with no statistically signif cant dif erences between the two groups (p = 0.5207). Further data regarding the group patterns and eating frequency are comparatively set out in Table II.

No considerable dif erences are seen regarding protein sources - meat (p=0.4910), cheeses (p=0.9586), oleaginous products (p=0.5129) or f sh (p=0.2902) between the two study groups.

Table II

Number of portions consumed in one day-descriptive statistics (mean±SD).

Indicator	Group of normal weight subjects (G1)	Group of underweight subjects (G2)
White meat	3.63±1.59	3.35±1.52
Red meat	1.88±1.36	2.1±1.22
Fish	1.22±0.92	1.13±1.05
Cheeses	1.97±1.19	1.97±1.33
Fruits	2.58±1.1	2.64±1.38
Vegetables	2.54±1.13	2.27±0.99
Fruit juice	0.33±0.76	0.21±0.41
Oleaginous products	1.33±0.85	1.29±0.98

Nutritional value of the eating scheme

As a result of the eating logs analyzed for the subjects belonging to the group of normal weight children (G1), a 17.03 gram protein ingestion could be observed, alongside the following results regarding the ingestion of minerals: 3.32 mg iron, 230.7 mg calcium, 59.55 mg magnesium, 645.9 mg potassium and 224.2 mg sodium. As for the underweight study group, there was a 19.38 gram protein ingestion, while the data regarding mineral intake were the following: 4.07 mg iron, 243 mg calcium, 76.2 mg magnesium, 534.1 mg potassium and 235.9 mg sodium. No considerable dif erences were seen between the two groups regarding protein (p=0.4642), iron (p=0.1269), calcium (p=0.8705), magnesium (p=0.1183), potassium (p=0.9127) or sodium (p=0.4899) daily intake.

Physical development vs. food ingestion

Protein ingestion was signif cantly correlated with the individual body height. Thus, a reduced protein intake was associated with a def cient body height growth, as seen in both G1 (p=0.048, r=0.254) and G2 study sample (p=0.004, r=0.399). However, in the normal weight sample group, protein ingestion was not signif cantly related to the body weight (p=0.067), age (p=0.432), body mass index (p=0.774), or to the daily intake of milk (p=0.818), white meat (p=0.279), f sh (p=0.875), cheeses (p=0.309) or oleaginous foods (p=0.402). The height of normal weight subjects was considerably inf uenced by the total consumption of meat (red and white meat: p=0.025, r=0.203) and cereals (p=0.012, r=0.227), whereas in the case of underweight subjects, the total consumption of meat (p=0.234) or cereals (p=0.393) was not a factor that af ected the individual body height development.

Table I

Anthropometric data – dif erences between the groups.

Indicator		Group of normal weight subjects (G1)	Group of underweight subjects (G2)	Dif erences between the medians (p value)
Height (cm)	Minimum value	71	84	
	Median value (CV%)	96 (10.34)	92 (7.05)	0.6616
	Maximum value	132	115	
Body mass index (BMI)	Minimum value	13.22	11.34	
	Median value (CV%)	15.5 (5.13)	13.58 (5.36)	< 0.0001
	Maximum value	17.47	14.2	

In the underweight sample (G2), protein intake was related to age (p=0.024, r=0.317), body weight (p=0.001, r=0.452), and the consumption of fruit juice (p=0.001, r=-0.428). However, no correlations were obtained regarding the intake of milk (p=0.353), cheeses (p=0.053), white meat (p=0.507), red meat (p=0.768) or oleaginous products (p=0.687). The changes in body mass index were related to the meat food products in the normal weight subjects (p=0.040, r=0.187) and to the cereal products in the underweight subjects (p=0.0007, r=-0.385), without reaching other signif cant associations (p>0.05).

Discussions

Our study aimed to analyze food intake and the changes in body development. No signif cant dif erences with regard to subjects' age were noticed within the study sample, as the two study groups had similar ages (38 months vs. 39 months). The main dif erence in terms of physical development was thus related to the body weight and the body mass index. No notable dif erences were obtained regarding the growth height between the two groups. However, the growing rate and the size upon measurement were inf uenced by the total amount of protein which was ingested, as seen in both G1 (p=0.048, r=0.254) and G2 (p=0.004, r=0.399) study groups.

In this respect, in the case of a protein-def cient diet, a diminishment of the growing rate along with a drop in the body height development can be seen. According to the data of Manary et al. (2016) regarding protein intake, not only the amount of protein is important in enhancing the risk of malnutrition or height growth def cit, but also the protein quality assessed through the PDCAAS score. According to Alderman et al. (2017), the cause of negative growth reports may also be related to several unbalanced eating habits seen until the age of 2, the height growing rate being thus slowed down ever since. Nonetheless, these data are not available in the case of our study, as the nutritional and anthropometric status at that age is unknown.

In the normal weight study group (G1), body height was inf uenced (p = 0.025) by the number of meat portions consumed (cumulated white meat and red meat, without including f sh), along with cereal based foods (p=0.012), without important correlations with other food groups. In G2 study group, body height growth was not related to meat (p=0.234) or cereal products (p=0.393). In G1 study group, the body mass index was inf uenced by the total milk intake (amount/ day; p=0.040, r=0.187), unlike G2. In G2 study group, the body mass index was negatively af ected by several other products: cereals and cereal-derived products (p=0.0007, r=0.385).

Recently published research shows that one of the main causes which induces changes in the body growth rate is hunger, due to a reduced social-economic income (Webb et al., 2018). Therefore, the basic problem is access to quality food. Nevertheless, access to food was not taken into account in this study; only the consumed food products were analyzed, without knowing whether the parent of ered a qualitative product or not (Raiten & Bremer, 2020). We also noticed an enhancement in the amount of proteins consumed with age (p=0.024, r=0.317). The total amount of proteins was lower in the low weight subjects (p=0.001, r=0.452) in relation to age.

A reduction in protein intake in G2 due to high intake of fruit juice (p=0.001, r=-0.428) was detected in this study. One possible cause for these results is satiety due to the amount of liquid along with an important quantity of simple carbohydrates, which brings the sensation of satiety by reaching the gastric volume by means of a protein-low beverage. According to the current European Society for Paediatric Gastroenterology, Hepatology and Nutrition Committee recommendations, the consumption of saccharides, especially sweetened drinks, must be limited in the case of children, due to the high risk of malnourishment, mostly expressed by excessive body weight (Fidler et al., 2017). Based on our results, fruit juice was associated with a def cit of protein-rich products, which, in turn, was subsequently associated with a lower body height. In this case, the current recommendations include increased attention paid to the sensation of satiety or hunger (Bentley & Nutly, 2020). Other research projects that analyzed food consumption in low ages concluded that the limitation of high calorie, sweetened or salted snacks that are however poor in nutrients was one of the main indicators for reaching a normal, balanced nutritional status in small age children (6 to 36 months old); yet, limiting daily intake can be important even after 36 months of age, as seen in our results (Green et al., 2019).

According to the FITS (Feeding Infants and Toddlers Studies) research project, the quality of children's menus and feeding habits has considerably increased with time, and the risk of malnutrition is thus lower; however, diet-related interventions are required at a high community level (national, governmental, etc.) or at an individual level, to improve children's eating habits (Duf y et al., 2002).

The study limitations are related to the study methodology, including the data collection phase, which involves a prospective eating log. This data collection method enhances the level of error. For future researches, the use of an eating frequency questionnaire, as well as an eating log should indicate the consumption of the main food groups and the cross-correlation of the two types of assessments, in order to rule out any inconsistent data.

Conclusions

1. The lack of protein intake was associated with changes in anthropometry development, with a drop in the height growth rate, irrespective of the body weight.
2. Positive changes in the body weight and the body mass index were related to protein and cereal/cereal-derived product intake.

Conf icts of interests

The authors declare no conf ict of interests.

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CASE REPORTS

Functional ef ects of hydrokinesiotherapy and underwater shower in tetramelic sensorimotor demyelinating polyneuropathy rehabilitation – a case study

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Abstract
The troubles of peripheral neuropathy are often found in Rehabilitation Clinics, because this disease af ects the functions of the locomotor system. The purpose of this study was to present a 41-year-old female patient from a rural area, diagnosed with Tetramelic Sensorimotor Demyelinating Polyneuropathy. She had followed a rehabilitation program in Colentina Clinical Hospital, Medical Rehabilitation Department, in August 2017, which included 3 sessions of hydrokinesiotherapy and underwater shower, one session with 1-2 days pause, in order to evaluate the clinical ef ects on the functional sensory and motor status. Thus, the intensity of burning sensations and headaches was measured with Visual Analog Scale, analytical articular and muscular testing was used, and data for body temperature, arterial pressure, pulse and blood glucose level, prior to and after each session were collected. The results show reducing of the intensity of the burning sensation and headaches, and various and inconstant muscular strength and global joint amplitude improvements.
Keywords: polyneuropathy, hydrokinesiotherapy, underwater shower, rehabilitation program, physical-kinetic therapy.

Introduction

Polyneuropathy is a neurological disease caused by damage to many peripheral nerves (nerves outside of the spinal cord and the brain), with a prevalence of 5-8% (Sommer at al., 2018) increasing with age (Hanewinckel at al., 2016). The troubles of peripheral neuropathy are often found in Neurological Rehabilitation Clinics and are among the most frequent neurological conditions with which physicians of all specialties are confronted (Watson & Dyck, 2015). Even if this disease may not directly af ect mortality and longevity, it still af ects the quality of life and activities of daily living (Hof man at al., 2015). The most common causes are: diabetes, alcoholism, chemotherapy, genetic causes, vitamin def ciency or overdose, toxic, immunological processes (Sommer at al., 2018). It is considered in the literature that almost half of the cases are idiopathic (Hanewinckel at al., 2016). The symptoms also vary from patient to patient. Sensitive symptoms are gradual manifestations of subjective and objective sensitivity of the feet or hands which can spread upward, pain during activities that should not cause pain. Motor symptoms and signs are walking dif culties, lack of coordination and falling, troubles of f ne motor skills, appearing from distal to proximal. When autonomic nerves are af ected, heat intolerance can appear, as well as excessive sweating or an inability to sweat, digestive problems, changes in blood pressure or in heart rate (1). Physiotherapy, exercises and ergotherapy can have benef ts, depending on the symptomatology and functional def cits of the patient (Akyuz & Kenis, 2014; Sommer at al., 2018).

Hydrokinesiotherapy is a method that combines the physiological ef ect of hydrotherapy in external care with kinesiotherapy which, in this way, is facilitated by the hydrostatic force. The warm bath at 35-36 ºC induces peripheral vasodilatation while reducing blood pressure, increasing heart rate and cardiac labor, and also reducing muscle tone and peripheral sensitivity with modif ed pain perception. It has a psychological ef ect of physical comfort and trust, which can be explained by the facilitation of body segment movements (Honda & Kamioka, 2012; Iłżecka, 2019). Underwater shower is a form of whirlpool using a tangential and inclined water jet on the treated surface, at a distance from the patient so as not to determine unpleasant sensations. The temperature of the water can be between 30 and 38 ºC and the pressure can range between 2 and 4 Kg/cm^2. It is well tolerated, and its therapeutic ef ects are antalgic, muscle relaxation (Dumitrașcu et al., 2012; Mooventhan & Nivethitha, 2014).

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Case study

The presentation of this case study, of images and data is made with the patient's informed consent. We are hereby presenting the case of a 41-year-old woman, with a height of 160 cm, a weight of 70 kg, from a rural area, a housewife, non-smoker, with occasional alcohol abuse - withdrawn 3 years before, known to suf er from demyelinating sensorimotor polyneuropathy, diagnosed in 2014 but with symptomatology reported 10 years before, which progressively aggravated (right>left). The diagnosis was conf rmed in 2017 after histopathological examination by right sural nerve and gastrocnemius muscle biopsy. The subject was hospitalized in the Colentina Clinical Hospital, Medical Rehabilitation Department, between 21st and - 31st of August, 2017. It is also worth mentioning the stressful physical everyday work she was exposed to (agricultural and housework). Secondary diagnoses were: obesity, ocular toxoplasmosis with left eye prosthesis since 2004; depressive anxious disorder; multiple drug allergy to pollen, dust and mold; left clubfoot – surgery in childhood with elongation of the Achilles tendon; intermittent cephalalgia improved with Cymbalta.

Assessment

At the time of admission, the subject presented frontal-parietal-occipital headaches - measured on the Visual Analog Scale (VAS) by 7/10, signif cant burning sensation in the lower extremities - measured on VAS by 8/10, without deep or superf cial sensitivity disorder, numbness in the upper limbs, globally diminished response of osteotendinous ref exes, without muscular atrophy; she was eupraxic, conscious.

Data collected following functional articular and muscular evaluation

Generalized joint stif ness; slight motor def cit on dif erent levels, more expressed in the right radiocarpal joint; ulnar deviation of the right hand by 30º and limited wrist extension by 50º; bilateral clubfeet, inversion - eversion of the foot not possible; in the right knee, anteroposterior hyperlaxity (hyperextension) and hypermobile patella; left genu valgus; walks without help, slightly balanced walk. Paraclinical exams disclose normal biological values.

Treatment

With the patient's informed consent, a specif c, complex rehabilitation program was initiated. This program included hygienic-dietary indications, medication, hydrokinesiotherapy in butterf y bath and underwater shower in 3 sessions, one session followed by 1-2 days pause, associated for 10 days with a daily physical-kinetic program adapted to the case. Physical treatment included galvanization of the lower limbs, ultrasounds in the paravertebral cervical and lumbar spine, laser in the radiocarpal joint, magnetic therapy of the lower limbs. The kinetic program included active and active with resistance exercises for muscle strength, walking, coordination and balance exercises, pelvic f oor strengthening exercises (***, 2019).

To better assess evolution, the subject was tested prior to and after each session of hydrokinesiotherapy and underwater shower, and all the values were then collected. For muscle testing, the Manual Muscle Testing Procedures were used (Clarkson, 2012); (2) and Range of Motion (ROM) was measured with a goniometer. We also collected data for body temperature, arterial pressure, pulse and blood glucose level to assess patient tolerance to the treatment. Subjective symptoms (burning sensation in the limbs and numbness, and also headaches) were evaluated before and after each session with VAS.

To study the ef ects of hydrokinesiotherapy and underwater shower we proposed the next goals:

- diminishing pain (burning sensation) and also headaches;
- poor posture, stif ness and musculotendinous retraction prevention and improvement for the extremities;
- mobility increase in the af ected joints and muscle strengthening;
- stimulation of peripheral proprioception because hydrostatic pressure is favorable to a better perception of the limb positions under the stimulus produced in water.

The subject was immersed in water at a temperature of 36.5ºC, in the butterf y tub, for 5 minute relaxation and after that, she underwent treatment consisting of passive mobilization of all the joints, especially the ankle-foot complex and the radiocarpal joint (to maintain the trophicity of cartilage, joint f exibility and to prevent poor posture), followed by global muscle strengthening exercises (Fig. 1).

Fig. 1 – Global muscle strengthening exercises.

The sessions consisted of global and analytical exercises using or against water resistance, followed by underwater shower with water at a pressure of 5 atmospheres and a temperature of 36.5ºC. The total duration of the procedure was 45 minutes - 1 hour (25-30 minutes underwater shower – for the upper and lower limbs). The performed exercises were sets of 10 repetitions of ROM movements for the upper and lower limb (Fig. 2).

Fig. 2 – ROM movements for the upper and lower limb.

Results and discussions

The results are collected in the individual Testing Chart for each session of hydrokinesiotherapy and underwater shower presented in Tables I, II, and III.

Table I

Testing Chart - First Session.

UPPER LIMB								
Region/ movement	**Joint testing**				**Muscle testing**			
	Left		**Right**		**Left**		**Right**	
SHOULDER	Before	After	Before	After	Before	After	Before	After
Flexion	150	150	150	160	4+	4+	4+	4+
Extension	65	65	65	65	4+	4+	4+	4+
Abduction	140	140	140	140	4+	4+	4+	4+
Internal rotation	80	90	70	90	4+	4+	4	4
External rotation	90	90	90	90	4-	4-	4-	4-
ELBOW								
Flexion	70	120	80	120	4+	4+	4+	4+
Extension	70	70	80	120	4-	4-4-	4+	4+
Ulnar inclination	55	80	30	55	4-	4+	4+	4+
Radial inclination	90	90	70	75	4+		4+	4+
RADIOCARPAL JOINT								
Flexion	52	52	70	70	4-	4-	4-	4-
Extension	50	60	50	50	4-	4-	4-	4-
Ulnar inclination	38	38	30 dev. 40	30 dev. 40	4-	4-	4-	4-
Radial inclination	40	40	0	0	4-	4-	1	1

LOWER LIMB								
Region/ movement	**Joint testing**				**Muscle testing**			
	Left		**Right**		**Left**		**Right**	
HIP	Before	After	Before	After	Before	After	Before	After
Flexion	75	80	80	85	4+	4+	4-	4-
Extension	18	20	20	20	4+	4+	4	4
Abduction	50	50	40	45	4-	4-	4+	4+
Internal rotation	35	40	40	40	4+	4+	4	4
External rotation	15	18	30	30	4-	4-	4-	4-
KNEE								
Flexion	75	90	90	90	4-	4-	4-	4-
Extension	70	80	80	85	4	4	4+	4+
ANKLE								
Plantar f exion	20	20	20	25	4+	4+	4	4
Dorsif exion	10	10	15	18	3+	3+	4-	4-
Inversion	0	0	0	0	0	0	0	0
Eversion	0	0	0	0	1	1	1	1

CLINICAL PARAMETERS			
	Before	**After**	**After 1H**
Blood pressure	120/60 mm Hg	100/70	130/70
Heart rate	84	84	78
Temperature °C	35.8 °C	37.2 °C	37.0 °C
Blood Glucose Level	140 mm/dl	143mg/dl	–

Table II

Testing Chart - Second Session.

UPPER LIMB								
Region/ movement	**Joint testing**				**Muscle testing**			
	Left		**Right**		**Left**		**Right**	
SHOULDER	Before	After	Before	After	Before	After	Before	After
Flexion	150	150	160	465	5	5	5	5
Extension	65	65	65	65	5	5	5	5
Abduction	140	140	140	140	5	5	4+	4+
Internal rotation	90	90	90	90	4+	4+	4	4
External rotation	90	90	90	90	4-	4-	4-	4-
ELBOW								
Flexion	120	140	120	120	4+	4+	4+	4+
Extension	120	140	120	120	4	4	4+	4+
Ulnar inclination	90	90	70	75	4+	4+	4	4
Radial inclination	80	90	70	75	4+	4+	4+	4+
RADIOCARPAL JOINT								
Flexion	52	52	70	70	4-	4-	4-	4-
Extension	60	50	50	50	4-	4-	4-	4-
Ulnar inclination	28	38	30 dev. 40	25 dev. 30	4+	4+	4-	4-
Radial inclination	25	35	10	18	4+	4+	3+	3+

LOWER LIMB								
Region/ movement	**Joint testing**				**Muscle testing**			
	Left		**Right**		**Left**		**Right**	
HIP	Before	After	Before	After	Before	After	Before	After
Flexion	80	85	85	85	4+	4+	4+	4+
Extension	20	20	20	20	4+	4+	4	4
Abduction	50	50	45	45	4	4	4+	4+
Internal rotation	35	40	40	40	4+	4+	4	4
External rotation	20	30	30	30	4	4	4+	4+
KNEE								
Flexion	90	90	95	95	4-	4	4+	4+
Extension	75	80	90	90	4+	4	4+	4+
ANKLE								
Plantar f exion	20	20	20	25	4+	4+	4	4
Dorsif exion	10	10	10	15	3+	3+	4-	4-
Inversion	0	0	0	0	0	0	0	0
Eversion	0	5	0	0	1	3	1	1

CLINICAL PARAMETERS			
	Before	**After**	**After 1H**
Blood pressure	130/80 mm Hg	120/60 mm Hg	100/70 mm Hg
Heart rate	84	84	78
Temperature °C	36.8 °C	37.2 °C	37 °C
Blood Glucose Level	140 mg/dl	143 mg/dl	–

Table III
Testing Chart - Third Session.

UPPER LIMB								
Region/ movement	**Joint testing**				**Muscle testing**			
	Left		**Right**		**Left**		**Right**	
SHOULDER	Before	After	Before	After	Before	After	Before	After
Flexion	150	155	170	170	5	5	5	5
Extension	68	75	68	75	5	5	5	5
Abduction	160	165	150	170	5	5	5	5
Internal rotation	90	90	90	90	4+	5	4	4+
External rotation	100	105	100	100	4+	4+	4+	4+
ELBOW								
Flexion	140	140	130	130	4+	5	4+	4+
Extension	140	140	140	140	4	4	4+	4+
Ulnar inclination	90	90	80	70	4+	4+	4+	4
Radial inclination	90	90	90	90	4+	4+	4+	4+
RADIOCARPAL JOINT								
Flexion	52	52	70	70	4-	4-	4-	4-
Extension	50	50	50	50	4-	4-	4-	4-
Ulnar inclination	40	40	20 dev. 25	20 dev. 28	4+	4+	4-	4-
Radial inclination	25	20	20	20	4+	1+	3+	3+
LOWER LIMB								
Region/ movement	**Joint testing**				**Muscle testing**			
	Left		**Right**		**Left**		**Right**	
HIP	Before	After	Before	After	Before	After	Before	After
Flexion	80	85	90	90	5	5	4+	5
Extension	30	30	30	30	4+	4+	4+	5
Abduction	50	50	50	50	5	5	4+	5
Internal rotation	35	40	40	40	4+	4+	4	4
External rotation	30	30	30	40	4	4+	4+	4+
KNEE								
Flexion	92	105	110	110	4-	4	4+	4+
Extension	80	70	70	85	4+	4+	4-	4-
ANKLE								
Plantar f exion	20	20	20	25	4+	4+	4	4
Dorsif exion	10	18	15	30	4-	4+	4+	4+
Inversion	0	0	0	0	0	0	0	0
Eversion	0	0	5	5	1	1	3	3

CLINICAL PARAMETERS			
	Before	**After**	**After 1H**
Blood pressure	140/80 mm Hg	130/90 mm Hg	140/80 mm Hg
Heart rate	88	90	90
Temperature °C	36.8 °C	36.8 °C	35.8 °C
Blood Glucose Level	119 mg/dl	130 mg/dl	–

There are data in the literature that present a relative ef ectiveness of hydrotherapy in the treatment of polyneuropathies (Barker et al., 2014; Heywood et al., 2017; Zivi et al., 2018); therefore, our study has a close-up view over each session of hydrotherapy to analyze the clinical ef ects and the role of this kind of therapy in the context in which our patient followed other types of physio-kinesiotherapies as well. The results show various and inconstant muscular strength and global joint amplitude improvements as follows:

In the shoulder, for f exion, on the right side, mobility increased from 160 to 170 after the third session. Muscle strength increased from 4 to 5 on both sides as early as the second session. For extension, at the third session, values increased by 10 degrees on both sides compared to the f rst session. For abduction, an increase in values for ROM and for muscle strength was obtained, but for internal rotation, the same passive mobility and the same muscular strength were obtained. For external rotation, an increase in mobility was obtained at the third session (before and after) and muscle strength increased from 4- at the f rst session to 4+ at the third session. In the elbow, there was an important increase in values for f exion on both sides, from 70 to 140 degrees on the left side (the testing before the f rst session compared to the testing after the third session). For extension, an important increase in values was obtained from 80 to 120 degrees even from the f rst session on the right side and at the second session the increase was even higher, to 140 degrees. For pronation, there was an increase in mobility on the right side, but values were the same for muscle strength. For the radiocarpal joint, ROM and muscle strength were the same until after the third session. For ulnar deviations on the right side, a reduction of the measured values from 30 to 20 degrees was obtained, and ulnar inclination was reduced from 40 to 28 degrees after the last session. For muscle strength, the value for the left side increased from 4- to 4+ even from the second session, and that value was maintained at the third session. Radial inclination was improved on the right side by reducing the cubital deviation for ROM (from 0 to 20) and for muscle strength (from 1 to 3+).

For the lower limb, hip mobility and muscle strength for f exion and extension were improved on both sides. Regarding abduction, the same values were obtained on both sides with no improvement, with one exception: an improvement of 5 degrees at the third session on the right side; muscle strength had a signif cant improvement from 4- to 5 on the left side after the third session. Internal rotation had no improvement at all, the values were the same for ROM and muscle strength. External rotation was improved by 15 degrees on the left side and by 10 degrees on the right side, but only at the end of the third session. For muscle strength, an improvement from 4- to 4+ for both sides was obtained. For the knee, f exion was improved on both sides by 20 degrees, and muscle strength was improved especially on the right side. For the ankle, the mobility of left plantar f exion was unchanged and for the right side there was a little improvement of 5 degrees after the bath from the second and third session; muscle strength was not improved. Dorsif exion showed low values of improvement after each bath, but with recurrence before the next session for ROM. For muscle strength, an improvement was obtained after the last session. For inversion, no dif erent results were obtained because this movement is completely impossible for both sides in association with clubfoot from childhood. For eversion, there was a 5 degree improvement on the left side after the second session, with recurrence before the next session, and on the right side 5 degrees were obtained until the f nal examination, and also an increase in muscle strength to up to 3.

Clinical parameters indicate a reduction of blood pressure after each session with reversion after 1 hour, in correlation with the literature, and no dif erence for heart rate, negatively correlated with the literature (Vizitiu &

Benedek, 2018), a slight increase of the body temperature only after the f rst and second session and a small enhancement of the blood glucose level (3 mg/dl for the f rst and second session and 13 mg/dl for the third session) indicating a good tolerance of the procedure.

The burning sensation in the lower limbs was reduced from 8 to 4 on VAS, and numbness also decreased even after the f rst session and was maintained until after the third session. Also, the intensity of headaches was reduced from 7 to 4-VAS, evaluated after the third session, which is in agreement with the literature data (Sujan et al., 2016).

It is interesting to notice that after the treatment course that the patient followed in August 2017, she asked at the next hospitalizations, in 2018 and 2019, the same kind of physical treatment, especially hydrokinesiotherapy and underwater shower, which proves the impact and the role of these physical therapies in patient's perception of the rehabilitation program.

Particularities of the case

- the inability to diagnose earlier; the subject complained of typical pain for many years prior to assessment (10 years);
- the association of bilateral clubfeet complicates functional status;
- physical labor and symptom neglect;
- signif cant visceral adipose tissue accumulation causing an imbalance in the pelvic area.

Prognosis

- ad vitam: good, if the patient has a balanced lifestyle, follows the treatment scheme, loses weight and exercises every day;
- ad functionam: favorable, but depending on the neural damage yet to come;
- ad laborum: satisfying, if she avoids fatigue, cold exposure and static postures.

Conclusions

1. Early onset of pain reduction (burning sensation and numbness).
2. Reducing the intensity of headaches.
3. Various and inconstant muscle strength and global joint amplitude improvements that need further research.
4. The treatment has good tolerance and a high psychological impact on the subject.

Conf ict of interest

No conf ict of interests.

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REVIEWS

The ef ects of exergaming on individuals with limb loss: a systematic review

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Abstract

Losing a limb is a life-changing experience. Af ected individuals (amputees) have reduced physical range of motion, poorer balance control, strength, and experience pain and fatigue. Exergaming is currently used in physical rehabilitation. There is currently no consensus on the ef cacy of exergaming delivered to people with missing limbs. This systematic review aims to evaluate and summarize the current research on the ef ects of exergaming among individuals with missing limbs. Studies reporting on exergaming intervention delivered to individuals receiving prosthetic rehabilitation were included in the analysis. Ten electronic databases were searched. Twelve articles were identif ed. Data were extracted and assessed for quality.

Three main categories of exergaming interventions comprised custom made exergames, Nintendo Wii and the Computer Assisted Rehabilitation Environment (CAREN) system. All participants in the studies were adults, except for one study which evaluated exergaming in adolescents and children. Studies reported improvements in EMG muscle control, cognitive-motor ability, walking capacity, function, balance and reduced pain, and positive experiences amongst most participants. Results suggest that exergaming supports improvements in physical activity, balance, cognition, emotional states, quality of life and pain.

Exergaming interventions administered to people with missing limbs show heterogeneity in protocol, duration and gaming platform. Although there was evidence of improved outcomes in participants, the ef cacy of exergaming is inconclusive due to varied dif erences in types of amputation, participant characteristics and assessed outcome measures. Nevertheless, reported enjoyment, acceptance and levels of motivation during exergaming appear to support the feasibility of exergaming for prosthetic training.

Keywords: amputees, exergaming, active video games, rehabilitation.

Introduction

Losing a limb is a life-changing experience and has negative impacts on the psychological and physical well-being of af ected individuals (Senra et al., 2012). People with limb amputations experience decreased levels of physical activity and impaired balance (Gaunaurd et al., 2011; Ku et al., 2014). They may also experience phantom limb pain for the residual limb (Kooijman et al., 2000; Nikolajsen & Jensen, 2001). Thus, rehabilitation through exercise may encourage physical functioning following amputation through the restoration of muscle strength, endurance, power and physical f exibility (Vestering et al., 2005).

Using exergaming for therapeutic purposes is gaining interest (van Diest et al., 2013). One of the most recent interventions currently used in physical rehabilitation is exergaming (Barry et al., 2014; Robinson et al., 2015; Tough et al., 2018). Exergaming can be def ned as physical exercise in a serious gaming environment enabled by digital technology (e.g. Nintendo Wii Fit) (Oh & Yang, 2010). It has been recommended as an appropriate form of rehabilitation for several clinical groups, including cerebral palsy related disabilities in paediatric patients and age-related disabilities in older people (Goble et al., 2014). Karahan et al. (2016) reported signif cant improvements in pain, disease activity, functional capacity and quality of life in people with ankylosing spondylitis after exergaming. Another study that evaluated the ef ectiveness of exergaming on balance reported not only improved balance and gait amongst people with multiple sclerosis, but also signif cantly higher improvements in gait whilst dual tasking after exergaming (Kramer et al., 2014).

Despite potential health benef ts of exergaming, there are dif erences in gaming pace and levels of cognitive complexity in certain exergames. For instance, people with Parkinson's disease have found dif culty in playing exergames that require fast physical movements (dos Santos Mendes et al., 2012). Therefore, using exergaming in rehabilitation must suit the therapeutic goal for which it

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was intended (Pirovano et al., 2016). Indeed, exergaming applications should support a wide range of physical exercises, allow the interventions to be personalized, involve the use of sensors that are comfortable to wear, and provide feedback to improve performance and encourage adherence without cognitive overload (Doyle et al., 2011).

Exergaming is a relatively new intervention in the rehabilitation of people with missing limbs (i.e. amputees) (Imam et al., 2018). To f ll this knowledge gap, the authors conducted a systematic review of the literature to look at exergaming interventions and related physical health outcomes from exergaming to provide a broad overview of exergaming ef ects in people with missing limbs, and to inform evidence-based clinical practice.

Methods

Our systematic review is retrospectively registered with PROSPERO (1). The reporting of this review is consistent with PRISMA guidelines (Liberati et al., 2009). In this review, the terms patient and participant are synonymous.

Search strategy

A systematic search was conducted in eight electronic databases from April 2019 and updated in August 2019. The electronic databases were the following: CiNAHL, Google Scholar, Cochrane Library, MEDLINE, ScienceDirect, SPORTDiscus, PEDro, and Web of Science (science and social science citation index).

The titles, abstracts and keywords of publications resulting from the searches, where applicable, were searched with the following search terms: rehabilitation or 'limb loss' or amput* or telerehab* or physiotherapy or gam* or wii or digital or video gam* or prostheti* or 'virtual reality' or 'augmented'. The references of included publications were also checked.

Screening process

The f rst author (JD) screened the initial 3,773 publications and removed duplicates from the initial search. All titles and abstracts were screened independently by the two authors (JD and IC). Any disagreements over publications were resolved through a discussion until a consensus was reached.

Study selection

Participants, intervention, comparisons (if any), outcomes and study design were used to identify the inclusion and exclusion criteria for the study.

Participants

We formulated our inclusion criteria to include individuals of all ages with missing limbs either due to surgical removal or traumatic disarticulation by injury or by surgical amputation. People awaiting diagnosis of amputation or surgery including individuals with congenital absence of limbs were excluded.

Intervention

Exergames must have encouraged physical movement or physical activity in order to interact with the game. They should have demonstrated at least some of the following characteristics: interactivity, cognitive-physical purpose, presence of an opponent or incentive to win points, exploration of a virtual environment by physical movement (e.g. walking in a virtual environment where the terrain is uneven which serves as "obstacles" or playing exergames by muscle activity) and the possibility of winning or losing.

Comparison

No comparative groups were required for inclusion.

Outcome measures

The outcomes were health related such as pain perception (i.e. phantom limb pain in amputees), balance, physical functioning and physical activity outcomes, including emotional states related to exergaming (i.e. motivation, acceptance of the exergaming intervention).

Study design

There were no limitations on trial design. However, reviews of the literature, articles from abstracts or summaries presented in a congress or conference were not included. Only articles available in English were included.

Data extraction

Data extraction was performed by one reviewer before being verif ed by the second reviewer. The following were extracted from selected studies: participant characteristics including type of amputation, details of intervention, equipment and setting, and clinical outcome measures. Two reviewers screened the articles independently. Any discrepancies were resolved through a discussion between the two reviewers. A third reviewer was consulted if there was a need for further resolve.

Risk of bias and quality of evidence

The Cochrane Collaboration Tool was used to assess risk of bias in randomized controlled trials (Higgins et al., 2011). The Cochrane Collaboration tool assesses biases as a judgement (high, low, or unclear) for individual elements from f ve domains (selection, performance, attrition, reporting, and other). The assessment of observational studies was conducted using the Quality Checklist for Healthcare Intervention Studies (Downs & Black, 1998). The Quality Checklist for Healthcare Intervention Studies comprises 27 questions covering f ve domains (study quality, external validity, study bias, confounding and selection bias and power). Any case reports, series or case studies were assessed using the IHE quality appraisal tool for case series studies (Guo et al., 2016; Moga et al., 2012). This quality appraisal tool is an 18-item questionnaire assessing the following: study objective, design, population, interventions, outcome measures, statistical analysis, results and conclusion, and competing interests and sources of support. Each article was assessed for risk of bias with the tools mentioned above by two reviewers working independently per study. Any disagreements were resolved through discussion between the reviewers.

Data analysis

A narrative synthesis of the f ndings from the selected studies was provided. The selected studies were described following their research design, sample population characteristics, exergaming intervention, timing of intervention delivery, setting and outcome measures.

Statistical analysis

A meta-analysis would have been conducted if the selected studies used the same type of intervention, sample population and reported similar outcome measures.

Results

Searches from eight electronic databases yielded a total of 3773 publications from which 236 were duplicates.

After excluding 3506 publications based on titles and abstracts, 31 publications were assessed in full-text, and 12 publications were included in the review (Fig. 1).

The 12 publications were published between 2010-2018 (2 in 2018, 3 in 2017, 1 in 2016, 2 in 2015, 1 in 2013, 2 in 2012 and 1 in 2010). The selected publications comprised 9 experimental intervention studies (2 RCTs (Imam et al., 2017; Prahm et al., 2018), single-subject study =1 (Prahm et al., 2017), case study = 2 (Ambron et al., 2018; Ortiz-Catalan et al., 2014), case reports = 3 (Chau et al., 2017; Miller et al., 2012; Sheehan et al., 2016) (Chau et al., 2017) and 4 feasibility studies (feasibility case series = 1 (Kruger, 2011), feasibility single-subject study = 2 (Imam et al., 2013; Tousignant et al., 2015) and feasibility between-group study = 1 (Andrysek et al., 2012). The exergaming research was conducted in two dif erent environments, respectively: research laboratories (4 university laboratories, 1 military medical laboratory) and clinical facilities (6 interventions were administered in hospitals, and one study also provided home-based rehabilitation interventions for the control group).

Study quality assessment

Two randomized controlled trials (Imam et al., 2017; Prahm et al., 2018) were included. When assessed for risk of bias using the Cochrane Collaboration's tool, no high risk of bias was detected for either study (Table I).

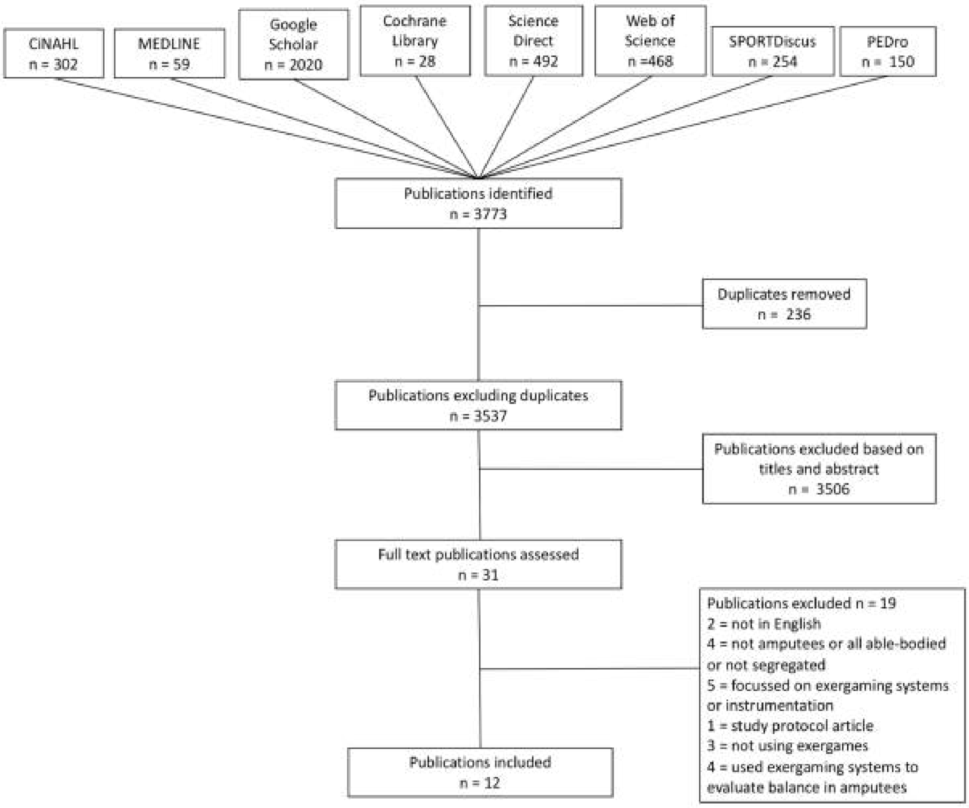

Fig. 1 – PRISMA f ow diagram of the literature search strategy used.

Table I
Study quality assessment for controlled trials using Cochrane Collaboration's Tool.

Indicator	Study	
	Prahm et al. (2018)	**Imam et al. (2017)**
Selection bias	Low - participants without limbs were randomised into two of three groups.	Low - participants without limbs were randomised into two groups.
Allocation concealment	Unclear – randomisation concealment not specif ed.	Low risk randomisation concealment was specif ed.
Performance bias	Unclear - blinding of participants not specif ed.	Unclear - blinding of participants not specif ed.
Detection bias	Unclear - blinding was not specif ed.	Low - parallel evaluator - blind RCT.
Attrition bias	Low - no missing outcome data.	Unclear - all outcome data was included despite 2 withdrawals and 1 lost to follow-up at T3.
Reporting bias	Low - all outcomes reported in suf cient detail.	Low - primary and secondary outcomes were reported in suf cient detail.
Other bias	Low - number of participants for a feasibility study.	Error in CONSORT f ow diagram feasibility indicators were not suf ciently reported.

Six publications (Ambron et al., 2018; Chau et al., 2017; Ortiz-Catalan et al., 2014; Sheehan et al., 2016) were assessed by the IHE quality appraisal tool for case series studies (Guo et al., 2016; Moga et al., 2012). These selected case reports, case series and case studies fulf lled most of the IHE checklist criteria (Table II).

The remaining four feasibility studies were assessed using the Quality Checklist for Healthcare Intervention Studies (Table III).

Table II
Quality assessment for case studies, case reports and case series using the IHE quality appraisal checklist (Gou et al., 2016; Moga et al., 2012).

Q	Ambron et al. (2018)	Chau et al. (2017)	Sheehan et al. (2016)	Ortiz-Catalan et al. (2014)	Miller et al. (2012)	Kruger (2011)
Q1	Y	Y	Y	Y	Y	Y
Q2	Y	Y	Y	Y	Y	N
Q3	U	U	N	U	U	U
Q4	U	U	U	U	U	U
Q5	Y	Y	Y	Y	Y	Y
Q6[1]	Y	Y	Y	Y	Y	Y
Q7	Y	Y	Y	Y	Y	Y
Q8	Y	Y	Y	Y	Y	Y
Q9	U	U	N	N	Y	N
Q10	Y	Y	Y	Y	Y	Pr
Q11	U	U	U	U	U	U
Q12	U	U	Y	Y	Y	Y
Q13	Y	Y	Y	Y	Y	Y
Q14	U	Y	Y	U	U	U
Q15	U	Pr	Y	Y	N	N
Q16	NA	NA	NA	NA	NA	NA
Q17	N	Y	Y	U	N	N
Q18	N	N	N	Y	N	Pr
Q19	Y[a]	Y	Y[a]	Y	Y	Pr[a]
Q20	Pr	Y	Y	Pr	Pr	Pr

Y yes, *N* no, *U* unclear, *Pr* partially reported, *I* description of eligibility for the study described as inclusion criteria, NA not applicable, [a] the Conclusion section is absent but conclusive arguments have been discussed in the article.

Table III
Quality assessment of observational studies using the Quality Checklist for Healthcare Intervention Studies (Downs & Black, 1998).

Q	Prahm et al. (2017)	Tousignant et al. (2015)	Imam et al. (2013)	Andrysek et al. (2012)
Q1	Y	Y	Y	Y
Q2	Y	Y	Y	Y
Q3	Y	Y	Y	Y
Q4	Y	Y	Y	Y
Q5	N	Y	Y	Y
Q6	Y	Y	Y	Y
Q7	Y	Y	Y	Y
Q8	N	N	N	Y
Q9	Y	Y	Y	Y
Q10	Y	N	Y	N
Q11	UD	UD	UD	UD
Q12	UD	UD	UD	UD
Q13	UD	Y	Y	Y
Q14	N	N	N	N
Q15	UD	UD	UD	UD
Q16	Y	Y	Y	Y
Q17	Y	Y	UD	Y
Q18	Y	Y	Y	Y
Q19	Y	Y	Y	Y
Q20	Y	Y	Y	Y
Q21	UD	Y	Y	Y
Q22	UD	Y	UD	UD
Q23	Y	N	N	N
Q24	N	N	N	N
Q25	N	N	N	Y
Q26	Y	Y	Y	Y
Q27	F	C	D	F
SUM	19	20	20	24

Y yes, *N* no, *UD* unable to determine, C = size of smallest intervention group is 3–4, D = size of smallest intervention group is 5–6, F = size of smallest intervention group >8.

They showed relatively good study quality with the lowest Downs and Black score being 19 (fair) and the highest being 24 (good), in consonance with scores previously reported (Hooper et al., 2008).

Study populations

Participants

The studies included in the review enrolled a total number of 105 participants from Canada (79) (Andrysek et al., 2012; Imam et al., 2017, 2013; Prahm et al., 2018; Tousignant et al., 2015), USA (18) (Ambron et al., 2018; Chau et al., 2017; Kruger, 2011; Miller et al., 2012; Sheehan et al., 2016), Austria (7) (Prahm et al., 2017) and Sweden (1) (Ortiz-Catalan et al., 2014) (Table IV).

Table IV

Participant characteristics and study details of included studies.

Author (date)	**Study design**	**Population: n enrolled, n completed/relevant (gender), mean age (range), location**	**Amputation**	**Timing of intervention delivery post-surgery (n)**	**Location**
Ambron et al. (2018)	Case-study	2, 2 (gender NS), age NS, USA	1 right transtibial, 1 left transtibial	11 months (1), 7 months (1)	University laboratory
Prahm et al. (2018)	Randomised controlled trial	14 amputees (gender NS), mean age NS, Canada -Control group = 10 (able-bodied) -Experimental (Group A, game-based rehabilitation) = 7 (transradial or transhumeral) -Experimental (Group B, Myoboy, standard rehabilitation tool) = 7 (transradial or transhumeral)	14 transradial or transhumeral	NS	Hospital
Prahm et al. (2017)	Single-subject study	7, 7 (gender NS), age NS, Austria	7 transradial or transhumeral	NS	University laboratory
Imam et al. (2017)	Randomised controlled trial	28, 23 (gender NS), 62^{mdn} (50-78), Canada -Control group = 14 (2 withdrawals before commencing) -Experimental = 14 (2 withdrawals before commencing, 1 drop-out)	Unilateral transtibial or transfemoral	Within 12 months (28)	Hospital
Chau et al. (2017)	Case report	1, 1 (1 male), 49, USA	1 right wrist disarticulation	5 months (1)	University laboratory
Sheehan et al. (2016)	Case report	1, 1 (1 male), 43, USA	1 right transfemoral	7 years (1)	Military medical laboratory
Ortiz-Catalan et al. (2014)	Case study	1, 1 (male), 72, Sweden	1 transradial	48 years (1)	Hospital
Tousignant et al. (2015)	Feasibility pilot single-subject study	3, 3 (gender NS), mean age NS, Canada	2 left transtibial, 1 left transfemoral	NS	Hospital
Imam et al. (2013)	Feasibility single-subject case study	8, 6 (5 male), 48.5^{m} (45 - 59), Canada	4 transtibial, 2 transfemoral	≤ 12 months (6)	Hospital
Miller et al. (2012)	Case report	2, 2 (2 male), 60 (NS), USA	2 transfemoral	32 months, 9 years	University laboratory
Andrysek et al. (2012)	Feasibility pilot between-group study	16 children and adolescents; control group (age-matched, non-amputee) = 10 (5 male), 10.7 (range NS) (mean age NS), experimental group = 6 (2 male); 11.8 (8 - 18), Canada	3 transfemoral, 3 Van Ness	Within 36 months (6)	Hospital (experimental group), participants' homes (control group)
Kruger (2011)	Feasibility case series	11, 11 (11 male), 28.9 (range NS), USA	2 right transtibial, 4 left transtibial, 1 right transfemoral, 1 left transtibial with right midfoot, 1 left transtibial with right knee disarticulation, 2 bilateral transfemoral	NS	Military medical laboratory

NS Not specif ed, ^{mdn} median age, ^{m} mean

Table V

Data summary of studies using exergames.

Author (Date)	System	Game	Intervention	Outcome measures (Method of assessment (signif cant f ndings))
Ambron et al. (2018)	Computerised video games	Quest for Fire, Web Browser, Chess and Checkers	2 sessions for the f rst individual, 4 sessions over six weeks for the second individual.	Pain intensity (VAS), usability (System Usability Scale)
Prahm et al. (2018)	Computerised video games via muscle control	2-dimensional labyrinth, racing game and rhythm game	Single session.	Muscle activity via EMG signals: maximum voluntary contraction (increased, $p = .02$ in groups and C), proportional precision control (in groups A and C, $p <.01$ for all target intensities, $p <.01$ for reaching low goal activation) in Group B, electrode separation (less activation in opposing electrode in all groups, p - .01 - .46; groups A and C, decrease in involuntary activation of opposing electrode for low intensity levels, $p = .02 - .04$) and muscle endurance (correlation between groups A and C, $p < .01$). - User experience (IMI: enjoyment of games more than Myoboy ($p < .01$). - User evaluation of game (custom questionnaire).
Prahm et al. (2017)	Computerised video games via muscle control	Pospos, Super Tux Kart, Step Mania 5	Single session.	-Muscle activity via EMG signals (precision control ($p < .01$), (electrode separation (signif cantly less activated during low goal activation levels), (endurance control ($p< .01$)). -User experience from playing the games (IMI), using the MyoBoy (IMI (lower enjoyment ($p = .02$)), enjoyment of EMG assessments (custom questionnaire). -User evaluation of game (custom questionnaire).
Imam et al. (2017)	Nintendo WiiFit™	- Experimental: Wii.n. Walk (WBB yoga, balance games, strength training and aerobics games) - Control: Wii Big Brain Academy™	3 sessions/week for 4 weeks, 40 min/session	Walking capacity (2MWT), functional tasks (SPPB), physical activity (PASE), balance conf dence (ABC), step activity (SAM), cognitive-motor (WWT), locomotor activity (LCI-5), feasibility parameters.
Chau et al. (2017)	Computerised video games	Interactive kitchen, Autoshield, Eleven: Table Tennis	5 sessions over several weeks, 45 min/session	Pain (VAS (55% decrease ($p = .0143$)), pain (SF-MPQ (60% decrease ($p = .023$)), pain (*WB FACES* (90% decrease ($p = .0024$))
Sheehan et al. (2016)	CAREN	Treadmill with virtual terrains (using randomised perturbations) - walking outdoors, hiking and playing golf	2 sessions/week for 4 weeks, 30 min/session	Walking speed (increase), improvement in functional stepping times, step width variability, stepping stability and margin of stability.
Ortiz-Catalan. (2014)	Computerised video games	Racing game (Trackmania Nations Forever)	Once a week for 13 weeks, followed by twice a week for 5 weeks.	Pain perception (McGill pain questionnaire), pain intensity (VAS). EMG signals: wrist pro/supination and elbow f exion/extension. Motion test: physical movements (Custom questionnaire).
Tousignant et al. (2015)	Nintendo Wii	WBB and WFg	5 sessions per week for 8 weeks	Walking (L test), Function and balance (AMPPRO), satisfaction (HCSQ), motivation (VAS), quality of life (TAPES).
Imam et al. (2013)	Nintendo WiiFit™	Yoga, balance games, strength training and aerobics games	5 sessions/week for 2 weeks (10 sessions) and a maximum of 6 weeks (30 sessions), 30 min/session	Walking capacity (2MWT (increase[2SD] in 5 patients)), functional tasks (SPPB (improvement in 4 patients)), functional mobility (L test (improvement in 2 patients)), balance conf dence (ABC (improvement[2SD] in 3 patients)), pain and fatigue (NRS), acceptability (SFQ-M).
Miller et al. (2012)	Nintendo WiiFit™ and BWS gait training	Wii games and aerobic balance training	2 sessions/week for 6 weeks, 20 min/session each of WiiFit™ and gait training	OUES, movement, dynamic balance, ABC, gait (GAITRite)
Andrysek et al. (2012)	Nintendo WiiFit™	Table Tilt and Tightrope Walk	4 sessions/week for 4 weeks, 20 min/session	Dynamic balance (COP), function and mobility (CB&M), feasibility (custom questionnaire and user logbook).
Kruger (2011)	CAREN	Continuous road, road with overhead targets	1 or 2 sessions/week for 4 to 8 weeks, 30 min/session	Walking speed (increase in self-selected velocities).

[2SD] 2 standard deviation band method of statistical signif cance, *2MWT* 2 Minute Walk Test, *SPPB* Short Physical Performance Battery, ABC Activities-Specif c Balance Conf dence scale, *AMPPRO* Amputee Mobility Predictor, *BWS* body weight support, *CAREN* Computer Assisted Rehabilitation Environment, *COP* centre of pressure, *CB&M* Community Balance and Mobility scale, *EMG* electromyography, *HCSQ* Health Care Satisfaction Questionnaire, *IMI* Intrinsic Motivation Inventory, *L* L-test of functional mobility, NRS numeric rating scale, ML mediolateral, *MyoBoy* assessment and training system, *OUES* oxygen uptake ef ciency slope, *PASE* Physical Activity Scale for the Elderly, *LCI-5* Locomotor Capability Index in Amputees, SAM Modus Health Stepwatch™ Activity Monitor, *SF-MPQ* Short-form McGill Pain Questionnaire, SFQ-M Short Feedback Questionnaire-modif ed, *TAPES* Trinity Amputation and Prosthesis Experience Scale, VAS visual analogue scale, *WBB* Wii Balance Board, *WB FACES* Wong-Baker Faces pain scores, *WFg* Wii Fit game.

Out of these, 88 were amputees and 17 were able-bodied. The participant population comprised individuals presenting either one extremity amputation or double amputation. One extremity amputees included: 55 lower limb amputees (14 transtibial, 28 transtibial or transfemoral, 10 transfemoral, 3 Van Ness) and 23 upper limb amputees (21 transradial or transhumeral, 1 wrist, 1 transradial). Double amputees included 4 individuals presenting: 1 left transtibial with right midfoot, 1 left transtibial with right knee disarticulation, 2 bilateral transfemoral. With regard to attrition, 1 dropout (at follow-up after pre- and post-testing) and 4 withdrawals were reported across these studies (Imam et al., 2017). A dropout refers to a participant who voluntarily withdraws his participation from a study, whereas a withdrawal refers to a well-weighed decision by research administrators to terminate participation of an individual, respectively. The reviewed studies included 16 children and adolescents, and 89 adults, within the age range of 8-78 years. The gender distribution was 28 male, 8 female and 70 non-specif ed. Only one study recorded participants' level of education (high school 32%, college 42.9%, university 25%), employment status (32% employed) and cognitive functioning (mean 29 scored from MMSE, range 23-30). In addition, they also recorded socket comfort for their participants (8 median score, range 4-10) (Imam et al., 2017).

Study interventions

Five of the included interventions used computerized video games for their exergaming intervention (Ambron et al., 2018; Chau et al., 2017; Ortiz-Catalan et al., 2014; Prahm et al., 2018; Prahm et al., 2017) (Table V).

The Nintendo Wii was used by f ve studies (Andrysek et al., 2012; Imam et al., 2017; Imam et al., 2013; Miller et al., 2012; Tousignant et al., 2015) and the remaining two studies used CAREN (Kruger, 2011; Sheehan et al., 2016). The reported duration ranged from 20 to 45 minutes per session. Not all durations were reported as sessions depending on each individual's adherence and motivation to persist. The duration of interventions ranged from one day to 8 weeks. Two studies included a comparison group of able-bodied individuals (Andrysek et al., 2012; Prahm et al., 2018), whereas one also included a comparison group of amputees (Imam et al., 2017). Andrysek et al. (Andrysek et al., 2012) presented the only study to use home-based exergaming for the experimental group (children with amputations). The study by Imam et al. (2017) used the Nintendo WiiFit™ and Wii Big Brain Academy™, played with a handheld remote control. Their exergaming intervention was designed to receive training at the hospital before undertaking unsupervised home-based exergaming. Prahm et al. (2018) used computerized video games played by muscle control and the Myoboy, a standard rehabilitation tool designed for muscle activity and prosthetic training. Collectively, intervention delivery occurred within 5 months to 48 years post-surgery. Four studies took place within twelve months post-surgery (Ambron et al., 2018; Chau et al., 2017; Imam et al., 2017; Imam et al. 2013). Andrysek et al. (2018) carried out their study within 36 months post-surgery. In the study by Ortiz-Catalan et al. (2014), their participant took part in the exergaming intervention 48 years post-surgery. Between-group comparisons were carried out in three studies (Prahm et al., 2018; Imam et al., 2017; Andrysek et al., 2017). Seven of the interventions were delivered by research staf (Ambron et al., 2018; Prahm et al., 2018; 2017; Imam et al., 2017; Chau et al., 2017; Ortiz-Catalan, 2014; Miller et al., 2012), three were delivered by physiotherapists (Sheehan et al., 2016; Kruger et al., 2011; Imam et al., 2013) and one study employed a physiotherapist and occupational therapist (Tousignant et al., 2014).

Outcome measures from exergaming interventions

Exergaming interventions were used to assess the following measures: pain (Ambron et al., 2018; Chau et al., 2017; Imam et al., 2013; Ortiz-Catalan et al., 2014), fatigue (Imam et al., 2013), physical functioning (Imam et al., 2017; Imam et al., 2013; Kruger, 2011; Sheehan et al., 2016; Tousignant et al., 2015), muscle control (Prahm et al. 2018; Prahm et al. 2017), feasibility (Andrysek et al., 2012; Imam et al., 2017), acceptability (Imam et al., 2013), quality of life (Tousignant et al., 2015) and user experience (Prahm et al., 2018; Prahm et al., 2017).

Pain and fatigue

The Visual Analogue Scale (VAS) was used to assess pain (Ambron et al., 2018; Chau et al., 2017; Ortiz-Catalan et al., 2014). Imam et al. (2013) used the Numerical Rating Scale (NRS), whereas Chau et al. (2017) used three pain rating scales (the Visual Analogue Scale (VAS), the short-form McGill Pain Questionnaire (SF-MPQ), and Wong-Baker FACES pain rating scale) to assess pain before and after the exergaming intervention. One study recorded fatigue scores by using a Short Feedback Questionnaire (SFQ-M) (Imam et al., 2013).

Physical functioning and mobility

The assessed outcomes were walking and step activity using the following: the 2 Minute Walk Test (2MWT) (Imam et al., 2017; Imam et al., 2013), L test (Imam et al., 2013; Tousignant et al., 2015) and computerized treadmill in combination with the Vicon motion capture system (Kruger, 2011; Sheehan et al., 2016). Imam et al. (2017) assessed the number of steps taken each day for a week using the Modus Health Stepwatch™ Activity Monitor (SAM), mounted on the prosthetic ankle. They also assessed self-reported physical activity by using the Physical Activity Scale for the Elderly (PASE). Cognitive-motor interaction was assessed using the Walking While Talking Test (WWT) (Imam et al., 2017), and locomotor activity was assessed using the Locomotor Capabilities Index in Amputees (LCI-5) (Imam et al., 2017). Tousignant et al. (2015) assessed functional mobility with a prosthesis using the Amputee Mobility Predictor (AMPPRO) questionnaire. Outcome measures for muscle control were levels of EMG control, f ne muscle activation and electrode separation assessed by using recorded electromyographic (EMG) biofeedback via myoelectric signals (Prahm et al., 2018; Prahm et al., 2017). Miller et al. (2012) was the only study to assess aerobic capacity whilst walking in older people with amputations.

The assessed outcomes for balance were balance conf dence using a self-administered subjective questionnaire called the Activities-Specif c Balance Conf dence (ABC) scale (Imam et al., 2017; Imam et al., 2013; Miller et al., 2012), centre of pressure (COP) displacements during quiet standing using the Nintendo Wii balance board (Andrysek et al., 2012), dynamic balance using the Biodex system (Miller et al., 2012) and functional balance using the Community Balance and Mobility Scale (CB&M) (Andrysek et al., 2012).

Feasibility and acceptability

Feasibility of the exergaming intervention was assessed using a customized questionnaire and a recorded logbook (Andrysek et al., 2012), whereas another study collectively assessed feasibility by considering outcome measures of safety and report of any adverse events from the exergaming intervention, post-intervention fatigue, pain levels, adherence and user acceptability of the exergaming intervention (Imam et al., 2013). User evaluation and acceptability of the games were assessed using a custom-made questionnaire (Prahm et al., 2017), System Usability Scale (Prahm et al., 2017) and the Short Feedback Questionnaire-modif ed (SFQ-M) (Imam et al., 2013).

Quality of life, motivation and user evaluation

One study assessed quality of life amongst amputees using the Trinity Amputation and Prosthesis Experience Scales (TAPES) (Tousignant et al., 2015). Motivation was assessed by using the Intrinsic Motivation Inventory (IMI) questionnaire (Prahm et al., 2018; Prahm et al., 2017), while another study used a custom made questionnaire to evaluate motivation by rating on a Visual Analogue Scale (VAS) and assessed patient satisfaction with health care services using the Health Care Satisfaction Questionnaire (HCSQ) (Tousignant et al., 2015).

Ef ects of the intervention

Two randomised controlled trials were included in this review. Imam et al. (2017) tested the ef ects of exergaming on walking capacity using the Nintento WiifFit™ for 12 sessions (over 4 weeks) compared with cognitive games using the Big Brain Academy Degree™ in older people with missing limbs. Their clinical outcome results were based on intention to treat analyses. Although there were no signif cant changes in the other outcomes, their results on walking capacity at post-intervention and 3-week retention were comparable to those of an RCT with younger individuals (Rau et al., 2007). Improvements were observed in walking capacity and cognitive-motor tasks in favour of the exergaming intervention (Wii.n.Walk). The overall adherence to the exergaming intervention was high, although in-home adherence was slightly lower than in-clinic adherence. Their patients preferred supervised group training and welcomed the convenience and accessibility of home-based exergaming.

Prahm et al. (2018) assessed short-term ef ects of exergaming on EMG muscle control in two patient groups and one control group comprising able-bodied participants. One of the patient groups served as a control, performing random EMG activations, whereas the experimental and able-bodied group played exergames (computerized video games). They found signif cantly increased maximum voluntary contractions in the groups that played the exergames, indicating stronger muscle contraction and improved muscle control. Improved proportional precision control was also observed in these groups for all EMG target intensities. The patient control group, however, showed signif cant improvement for the middle intensity target. Although there was overall improvement in muscle separation in almost every instance, these results were not always signif cant. Only the groups that played exergames showed signif cant decreases of involuntary activation of the opposing electrode for the f rst to third measurements for low goal intensity levels. Improved endurance and muscle isolation was also found in favour of exergaming. Their patients signif cantly enjoyed playing the exergames and perceived the MyoBoy to be a useful EMG training tool. In terms of exergame evaluation, they preferred rhythm and racing games. Racing games scored slightly higher motivational scores.

Three of the twelve studies evaluated whether pain improved after an exergaming intervention (Ambron et al., 2018; Chau et al., 2017; Ortiz-Catalan et al., 2014). All three reported reductions in pain intensity. Ambron et al. (2018) found lower pain intensity ratings at post-intervention, but were not able to establish the association between pain and level of fatigue. The patient in the study of Chau et al. (2017) reported signif cant pain relief taking ef ect approximately 24 hours after each exergaming session. There was also a decrease in pain, lasting progressively longer for several days after each exergaming session. Follow-up feedback on pain one week post-intervention reported continued pain relief over f ve days after the last exergaming session and an overall decrease in baseline pain levels. At six weeks follow-up, the patient reported that the pain was still present but generally decreased in severity and was much more tolerable. This indicates longer lasting benef ts retained after exergaming. The results of Ortiz-Catalan et al. (2014) were especially interesting where the patient experienced an increment of pain at the beginning of the exergaming intervention, followed by reduced pain intensity after 4 weeks and pain-free periods after 10 weeks, which then developed into completely pain-free periods a couple of sessions later. Although pain was not their primary clinical outcome, Imam et al. (2013) reported post-intervention pain and fatigue scores which ranged less than 6 on a scale of 0 to 10 (0 = no pain; 10 = extreme pain and 0 = no fatigue, 10 = extreme fatigue). They also reported high adherence (80%) to their reported median scores for pain and fatigue, suggesting benef cial ef ects on phantom limb pain from exergaming in amputees.

The studies that used CAREN to evaluate clinical outcomes found improvements in walking, gait, physical functioning and balance, including progression of level walking to more challenging terrain (Kruger, 2011; Sheehan et al., 2016). One of the studies demonstrated evidence of retaining benef ts in gait at least 5 weeks after the f nal exergaming session (Sheehan et al., 2016). The other reviewed studies found improvements favouring the exergaming group in some of the outcomes assessed, such as better muscle control (Prahm et al., 2017), dynamic balance (Miller et al., 2012) and balance conf dence (Imam et al., 2017; Imam et al., 2013; Miller et al., 2012). One study (Andrysek et al., 2012) showed dif erences in functional balance and mobility between patient groups, where patients with transfemoral amputations scored lower than those of the Van Ness group despite overall improvement in functional balance and mobility (CB&M) scores between baseline, at post-intervention and follow-up. Another study found high levels of motivation after exergaming amongst patients (Tousignant et al., 2015). Study participants demonstrated positive responses in terms of acceptability of exergaming (Imam et al., 2013).

Discussions

This is the first systematic review to evaluate and summarize current literature concerning the effects of exergaming on individuals with missing limbs. The interventions we found through this review showed variability from one another in terms of clinical and methodological diversity. Hence, it is difficult to conclude which method of delivery would prove to be the most advantageous.

Exergaming interventions in the reviewed studies had different therapeutic targets and varied in terms of participants, duration, gaming design and strategies, whether it was to improve balance and stability responses through repeated practice (Sheehan et al., 2016), to provide treatment for phantom limb pain (Ambron et al., 2018) or to improve muscle control (Prahm et al., 2018). The Nintendo WiiFit™ was the most used intervention in studies involving people with lower extremity amputations, whereas computerized video games were used in the studies involving people with upper extremity amputations. Only one study using computerized video games involved two individuals with lower extremity amputations, whereby one patient (with left transtibial amputation) reported reduced pain severity after exergaming and a progressive decrease in phantom limb pain across the exergaming sessions (Ambron et al., 2018). This suggests the suitability of exergaming interventions across different types of amputations in individuals.

In terms of clinical benefit, exergaming was seen to improve mobility and balance (Andrysek et al., 2012; Imam et al., 2017; Imam et al., 2013; Kruger, 2011; Miller et al., 2012; Sheehan et al., 2016; Tousignant et al., 2015) when assessed through the current review, showing alignment with previous exergaming studies involving able-bodied clinical groups (Hung et al., 2014; Karahan et al., 2016; Robinson et al., 2015). The studies that used CAREN found improved outcomes in their participants individually, particularly in walking and balance (Kruger, 2011; Sheehan et al., 2016).

Pain was assessed in three studies in this review (Ambron et al., 2018; Chau et al., 2017; Ortiz-Catalan et al., 2014), showing improvements following the exergaming intervention. These findings are consistent with those of Pekyavas & Ergun (2017), who compared the Wii with a home exercise programme provided to patients with subacromial impingement syndrome (SAIS). They found that the exergaming group demonstrated significantly better improvements in range of movement in the shoulder and scapular rotation and retraction compared to the home exercise group, despite improvements in pain in both groups after exergaming.

The current review was unable to find strong evidence of long-term benefits from exergaming. However, from the studies assessed, exergaming interventions appear to confer at least short-term benefits to people with amputations, where one study demonstrated evidence in the retainment of improved gait at least five weeks after the last exergaming session (Sheehan et al., 2016). This is similar to a study by Sims et al. (2013), which evaluated the effects of exergaming on static postural control in able-bodied people with a history of lower limb injury. In addition to improved static postural control after exergaming, they found significant improvement in self-reported function at four weeks post-intervention.

Patient motivation and adherence to rehabilitation encourage recovery and improved health outcomes in patients (Maclean & Pound, 2000). Findings from the studies reviewed showed increased motivation amongst patients after exergaming (Imam et al., 2017; Prahm et al., 2018; Prahm et al., 2017). For instance, rhythm and racing games were perceived to be more enjoyable than dexterity games, and motivation scores were rated higher in racing games when compared to rhythm games (Imam et al., 2017). The single participant in the study of Sheehan et al. (2016) attributed the benefits to exergaming; he believed that interacting with the exergaming intervention had challenged him to focus on the surroundings and to make necessary gait and posture changes in order to play the exergames. The participants in the study of Miller et al. (2012) found exergaming to be challenging and enjoyable. Participants in the study by Tousignant et al. (2015) demonstrated high motivation and adherence to the exergaming intervention and were satisfied with the service provided. They also scored highly on the Health Care Satisfaction Questionnaire (97%, 100% and 84%, respectively).

Because the included studies showed wide heterogeneity, it is difficult to draw firm conclusions in the delivery of interventions and the clinical outcome measures assessed within the selected studies. Nevertheless, exergaming interventions appear to be feasible and favourably received by individuals with missing limbs. A high degree of adherence and a low level of dropouts from the reviewed studies indicated high acceptance regarding the proposed exergaming interventions, including both immersive and non-immersive virtual reality designs. Of all the included studies, there was one which had the only lost to follow-up participant (Imam et al., 2017). The participant developed complications with preexisting lung disease, unrelated to the study. In spite of this, adherence to the study was 83.4% (Imam et al., 2017).

With regard to feasibility, the exergaming sessions were well accepted and received positive feedback from participants (Chau et al., 2017). Participants in the study of Andrysek et al. (2102) perceived the exergames to be fun and easy to play. Furthermore, participants in Prahm et al.'s study (2018) significantly enjoyed exergaming, even though the required physical movements put more pressure on them. Participants in the study by Imam et al. (2017) were willing to exert more physical effort to play the exergames in comparison to using the MyoBoy. They perceived the exergaming intervention to be useful for improving their walking abilities and intended to continue using the equipment at home on a regular basis (Imam et al., 2017). Usability of exergaming interventions also received favourable ratings in the study of Ambron et al. (2018), where the majority of ratings via the System Usability Scale questionnaire fell within the acceptable range of above 50 out of 100, where scores of 70+ mean good prospective usability for an information technology-based application in development (Sauro, 2011). Nevertheless, there was also report of low ratings in usability for one of the exergames called Quest for Fire by one participant, ref ecting the frustration encountered whilst learning to move the avatar around the labyrinth (Ambron et al., 2018). With regard to safety, 4 near-fall incidents while exergaming with lower limb prostheses were recorded by Andrysek et al. (2012). Nonetheless, there was no report of adverse ef ects related to the exergaming interventions.

With respect to quality of life, one of the domains of life classif ed by the International Classif cation of Functioning, Disability and Health (ICF) is mobility (2). In fact, the benef ts of exergaming derived from the variety of exergames and complex challenges presented to the user are not limited to improved functional parameters, but instead, also encompass domains directly inf uencing the quality of life of the participants. For instance, reducing pain at phantom limb level, improving prosthesis control, self-conf dence and outdoor environment ambulation management, as related by participants in the reviewed studies (Ambron et al., 2018; Sheehan et al., 2016). One participant in the study of Ambron et al. (2018) reported dramatic improvements in his physical activity over the course of the exergaming intervention. After two exergaming sessions, he successfully walked to the local grocery store using a lower-limb prosthesis for the f rst time after amputation. The participant attributed his improved physical activity to exergaming training. Feedback from the participant in Chau et al.'s study (2017) was also promising. He stated that playing the exergames made him forget the pain, move as if the pain was not there and he felt normal. His remark *"I feel like my hand is back*" is an especially important response to exergaming as this ref ects the potential therapeutic benef t from exergaming on physical recovery and movements on a residual limb.

The current review is not without limitations. The selected studies showed great heterogeneity. The study protocols dif ered in terms of exergaming intervention and length of therapy sessions. Furthermore, the exergaming interventions from the reviewed studies dif ered in frequency, duration, gaming elements, and physical and cognitive user tasks. The actual power of the studies is also limited by the low number of participants enrolled. Outcome measures also dif ered in assessment methods. Due to the scarcity of literature for exergaming in people with amputations, more research should be conducted to explore common clinical outcomes from exergaming interventions, suitable for individuals with dif erent types of amputations. Future research should also assess longer follow-ups post-intervention in order to evaluate the ef ects of exergaming over time.

Conclusions

Upon completion of the current review, we concluded that:

1. There was a wide variability in the studies assessed. Due to the heterogeneity of the included studies, we were unable to conclude about the ef ectiveness of exergaming.

2. However, there was evidence of improved health outcomes after exergaming, feasibility and acceptance of the exergaming interventions to suggest that exergaming may be potentially therapeutic for people with missing limbs.

Conf icts of interests
The authors have none to declare.

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Pelvis mobility control solutions for gait rehabilitation systems: a review

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Abstract

Pelvis mobility plays a big role during normal walking. There are six pelvic movements that allow natural gait patterns and center of mass trajectories. The pelvis mechanism is an underdeveloped component in gait rehabilitation systems. Mobility constraints and human-robot joint misalignment appear during gait if pelvis motion is restricted or not actuated. This is why systems should provide pelvis mobility control.

The aim of this review is to help researchers identify weaknesses and come up with solutions for new generations of gait rehabilitation devices.

The data on current gait systems with pelvic mechanisms was collected from various databases on 26 August 2020. The selection criteria included all devices that had at least one pelvic degree of freedom actuated by a pelvis mechanism and excluded all devices with all pelvic degrees of freedom passive or restricted and all devices with pelvic support only for registering data and not for controlling pelvic motion.

A number of 16 devices were identif ed. Dif erent characteristics are compared, including: the type of system, the system mechanical components, the type of surface, the pelvic robot – human interface, the allowed human pelvis movements and the types of pelvic movements (actuated, free or blocked), the pelvis actuation, the operating modes and the center of mass trajectory.

There is no perfect system; each one of them has both strong and weak points. Research directions are suggested for system improvements that might help future gait rehabilitation devices.

Keywords: pelvis mechanism, pelvic movement, gait rehabilitation, overground, exoskeleton.

Introduction

The requirements needed for walking are: a) neurological, such as equilibrium and trunk stability (the ability to assume the upright position and maintain balance); b) locomotion related (the ability to initiate and maintain rhythmic stepping); c) non-neurological, such as good range of motion and ef cacious muscles (Giladi et al., 2002; Jung et al., 2018). Walking is impossible if there is no reaction force when touching the ground (Lim et al., 2011).

Saunders et al.'s theory about the six determinants of gait states that mechanisms at knee, foot and hip level, together with pelvic movements are responsible for reducing the vertical movement of the center of mass (CoM) (Saunders et al., 1953). The six determinants are pelvic transverse rotation, pelvic tilt, stance phase knee, f exion, knee mechanisms, foot mechanisms, and lateral displacement of the pelvis. Three out of the six determinants are pelvic motions, which highlight the importance of pelvic control during gait rehabilitation (Lim et al., 2011).

The pelvis is the center of the body weight and the link between the lower limbs and the trunk, and therefore it has an important role in maintaining the trunk in upright position (trunk stability), in maintaining balance and in ensuring the movement of the lower limbs (Torricelli et al., 2016; Ventura et al., 2015).

During walking, there are six pelvic movements described in all three planes (Ayad et al., 2019): 3 translations: mediolateral (left/right); anteroposterior (forward/backward); superior-inferior (up/down) and 3 rotations or angular displacements (Table I).

Table I
Pelvic rotations.

Name	About which axis	In what plane
Transverse rotation (internal-external rotation)	Vertical	Transverse (horizontal)
Tilt (antero-posterior rotation)	Transverse (medio-lateral)	Sagittal (longitudinal)
Obliquity (up-down rotation)	Sagittal	Coronal (frontal)

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The frequency, amplitude and mean position of the pelvic oscillations during walking depend on the following parameters: walking speed, stride length and step rate (Ijspeert, 2014; Lim et al., 2011; Torricelli et al., 2016). Therefore, pelvic motion adaptation is required when an external intervention changes these gait parameters (Vashista, 2015).

When walking at natural speeds, the CoM follows an undulating path with amplitudes of about 5 cm in the mediolateral and vertical directions. In addition, pelvic mediolateral displacement allows weight shift towards the stance foot, moving the CoM above this leg (Vashista, 2015). The CoM path in the sagittal plane is determined by: hip flexion, stance knee flexion, and ankle-foot interaction (composed of ankle plantar flexion, toe flexion and the displacement of the center of pressure). In the coronal plane, the mediolateral path of the CoM is determined by hip adduction and pelvic tilt. The vertical path of the CoM is determined by pelvic rotation and pelvic tilt (Lin et al., 2014).

Pelvic motion influences balance during walking due to the proximity to the body's CoM (Endo & Herr, 2014). For example, the vertical motion of the pelvis enables the vertical displacement of the CoM. This enables the exchange of gravitational potential and kinetic energy during walking (Gonzalez-Vargas et al., 2015). Pelvic motion allows the transfer of forces from the lower extremity to the trunk, and thus helps in the forward propulsion of the body (Lim et al., 2011). Inertia or mobility constraints produce changes in the pelvic motion and require adaptation of lower limb motion (Vashista, 2015).

The most important modules a system should have are: body weight support (BWS) subsystem, reciprocal stepping mechanism (or cyclical leg movement mechanism), body weight shifting module, pelvis mechanism (or pelvis motor unit) and environmental module (Ayad et al., 2019).

The priorities of the development of systems are usually the higher number of degrees of freedom (DoFs) and the wide range of motion. Lightweight and high dynamic driving mechanism are taken less into consideration and free movement has the lowest priority (Ayad et al., 2019).

Another underdeveloped component is the pelvis mechanism. It is necessary to develop multi-DoF pelvis mechanisms that provide assistive force field to the pelvis and permit natural pelvis movement during gait training (Olenšek et al., 2016). If the system does not provide control of all six DoFs of the pelvis, then mobility constraints and human-robot joint misalignment occur during gait (Vashista et al., 2016). Unconstrained pelvis movement is essential for assessing balance during walking. Gait characteristics are changed when the pelvis is fixated and its DoFs reduced. This can lead to improper execution of balance responses (Olenšek et al., 2016). The restrictions of the pelvic movements also affect the joints of the legs and lead to abnormal gait patterns (Jung et al., 2018).

There are different approaches that have been proposed to address these needs, but further research is needed (Olenšek et al., 2016). The means of evaluating the pelvis mechanism are: DoF, range of motion, backdrivability and free movement (Ayad et al., 2019).

Gait Rehabilitation Systems Identification

This review focuses on gait rehabilitation systems that have pelvic mechanisms. The aim of the review is to help researchers identify weaknesses and come up with solutions for new generations of gait rehabilitation devices.

Identification of systems:

The data on current gait systems with pelvic mechanisms was collected on 26 August 2020 from the following databases: PubMed, IEEE Xplore, ResearchGate and Web of Science. The search terms used were:

((robot*) OR (robot-assisted) OR (exoskeleton) OR (orthosis) OR (end-effector) OR (treadmill) OR (overground) OR (over ground) OR (system) OR (device) OR (manipulator)) AND ((gait*) OR (walk*) OR (locomotion)) AND ((pelvic motion) OR (pelvic translation) OR (pelvic rotation) OR (pelvic tilt) OR (pelvic obliquity) OR (pelvic mechanism) OR (pelvic module) OR (pelvic subsystem) OR (pelvic driven) OR (pelvic unit) OR (pelvic device) OR (pelvic support*) OR (pelvic control) OR (pelvis control) OR (pelvic assist*))

ScienceDirect and Scopus were omitted because the search engine does not support so many Boolean connectors. The "*" sign was used to replace all derived words (e.g. robotic for robot*).

Inclusion criteria:

All devices that have at least one pelvic DoF actuated by a pelvis mechanism.

Exclusion criteria:

All devices with all pelvic DoFs passive or restricted; devices with pelvic support only for registering data and not for controlling pelvic motion.

Selection:

The first 100 articles (sorted by relevance/best match) from each database search results were taken into consideration and 16 devices were identified. If a system had more versions/prototypes, the latest one to meet the criteria was chosen.

Gait Rehabilitation Systems Characteristics

The characteristics of the 16 identified devices are shown in Tables II-VII. The order in which the systems are presented is random.

The names of the systems are included in Table II along with their general characteristics: i) type of system; ii) mechanical components of the system and whether it has a BWS subsystem or not; iii) whether the system has an intention recognition subsystem or not; iv) over what type of surface the user can walk; v) the type of robot-human interface the system has at pelvic level; vi) the years of first and latest research papers found regarding the system. In order to find the date of the research papers, the name of each system was searched again in the same databases.

Table III offers information on the movements the human pelvis can make while using each system. Table IV gives information about the actuation of the system's mechanical parts that enable human pelvis movements, while Table V describes whether the movement is actuated, passive or blocked. Table VI offers information on the operating modes under which the systems can perform and Table VII whether the systems affect the CoM trajectory or not.

No information was obtained in what concerns the range of motion that the pelvis mechanism provides for any of the movements, with one exception: the Lokomat Pro (Table III).

Table II
Systems with pelvic mechanism.

System /Name	Type of system	System mechanical components		Intention recognition control subsystem		Type of surface	Pelvic robot-human interface	Year of f rst research paper	Year of latest research paper
		BWS[1] system	Others	FES[2]	Others				
Lopes II Alingh et al. (2019); Meuleman et al. (2016); Ekkelenkamp et al. (2007); Veneman (2007); Veneman et al. (2007)	Exoskeleton	Yes (cBWS[3])	Exoskeleton Treadmill	No	No	Treadmill	Harness	2016	2019
PAM (Pelvic Assist Manipulator) Aoyagi et al. (2007); Ichinose et al. (2003)	Pelvic manipulator	Yes (cBWS)	2 pneumatic robots Treadmill	No	No	Treadmill	Pelvic belt	2003	2007
NaTUre-Gaits II (Natural and Tunable Rehabilitation Gait System) Lim at al. (2011); Trieu Phat Luu et al. (2014)	Overground	Yes (sBWS[4] integrated in the PA pelvis mechanism + cBWS)	Pelvic Assistance (PA) Mechanism Mobile Platform Robotic Orthosis	No	No	Flat	Contact surface at hip joint with the end ef ectors	2011	2014
Stand Trainer[5] Khan et al. (2018)	Cable-driven robot	Cable-driven pelvic robot which can support the body weight of the user Force plates		No	No	Force plates or treadmill	Pelvic and trunk belts on which cables are attached	2018	2018
WalkTrainer Stauf er et al. (2009); Stauf er et al. (2008); Stauf er et al. (2007); Yves et al. (2010)	Overground	Yes (cBWS)	Leg orthosis Pelvic orthosis Muscle stimulator Deambulator (the frame)	Yes (CLEMS[6])	No	Flat	Belt + Pelvic rigid orthosis	2007	2010
Lokomat Pro Aurich-Schuler et al. (2019a); Aurich-Schuler et al. (2019b); Aurich-Schuler et al. (2017)	Exoskeleton	Yes (cBWS)	Exoskeleton FreeD module Treadmill	No	No	Treadmill	Harness + Back pelvis contact	2017	2019
ALEX III (Active Leg Exoskeletons) Stegall et al. (2017); Zanotto et al. (2014); Zanotto et al. (2013)	Exoskeleton	No	Exoskeleton Support platform Treadmill	No	No	Treadmill	Belt + Pelvic rigid frame	2013	2017
RGR Trainer (Robotic Gait Rehabilitation Trainer) Pietrusinski et al. (2014); Pietrusinski et al. (2012); Pietrusinski et al. (2010a); Pietrusinski et al. (2010b)	Exoskeleton	No	Exoskeleton Treadmill Stationary frame	No	No	Treadmill	Pelvic brace	2010	2014
JARoW-II (JAIST Active Robotic Walker) Ohnuma et al. (2017)	Overground	No	Upper frame with pelvis mechanism and base frame with omni-wheels unit	No	No	Flat	Pelvic brace	2017	2017
IBWS (Ischiatic body weight support system) (Salgcuero-Beltrán et al.(2012)	Assistive manipulator	Yes (sBWS integrated in the pelvis mechanism)	Assistive manipulator Treadmill	No	No	Treadmill	Pelvic socket	2012	2012
COWALK Jung et al. (2018); Jung et al. (2014)	Exoskeleton	Yes (cBWS)	Exoskeleton leg unit Gravity compensation unit Pelvis motion unit Treadmill	No	No	Treadmill	Pelvic brace	2014	2018
AssistOn-Gait Munawar et al. (2015; Munawar et al. (2016)	Overground	Yes (cBWS)	Mobile base Pelvis-hip exoskeleton	No	No	Flat	Harness with back support	2015	2016
Gait Rehabilitation Robot Liu et al. (2016); Watanabe et al. (2010)	Pelvic manipulator	Yes (sBWS integrated in the pelvis mechanism for PBWS[7])	Split treadmill Pelvic support manipulator Visual interface	No	No	Treadmill	Pelvic frame	2010	2016
Lower Limb Rehabilitation Robot Shi et al. (2014)	Exoskeleton	Yes (sBWS integrated in the pelvis mechanism)	Exoskeleton Walker Treadmill	No	No	Treadmill	Back pelvis and back trunk contact	2014	2014
String-man (Surdilovic et al., 2007; 2004)	Wire-robot	Wires for PBWS and for controlling posture Treadmill		No	No	Treadmill	Harness (corsage)	2004	2007
TPMAD (Trunk and Pelvis Motion Assistance Device) Hashimoto et al. (2018)	Hip and chest orthosis	No	Hip mount Chest mount Flexible shaft between them	No	No	Any	Hip mount	2018	2018

[1]BWS = body weight support, [2]FES = functional electric stimulation, [3]cBWS = cable harness BWS, [4]sBWS = structural harness BWS, [5]Stand Trainer is the upgraded version of A-TPAD, (Active Tethered Pelvic Assist Device) and TruST (Trunk Support Trainer), [6]CLEMS = Closed loop electrical muscle stimulation, [7]PBWS = partial body weight support

Table III
Allowed human pelvis movements.

System Name	Human pelvis movements allowed	
	Translations	**Rotations**
Lopes II	All three	All three
PAM	All three	All three
NaTUre-Gaits II	All three	All three
Stand Trainer	All three	All three
WalkTrainer	All three	All three
Lokomat Pro	Medio-lateral translation up to 4 cm (per side) Vertical translation	Transverse rotation up to [4]O
ALEX III	All three	Transverse rotation Obliquity
RGR Trainer	All three	All three
JARoW-II	All three	All three
IBWS	All three	All three
COWALK	All three	Transverse rotation
AssistOn-Gait	All three	Transverse rotation Tilt
Gait Rehabilitation Robot	Medio-lateral translation Vertical translation	Transverse rotation
Lower Limb Rehabilitation Robot	Medio-lateral translation Vertical translation N/A for the antero-posterior translation and for the rotations	
String-man	All three	All three
TPMAD	All three	All three

Table IV
Pelvis actuation.

System Name	System actuated DoFs[1] for pelvis movements			Type of actuators that enable pelvis movements
	Total actuated DoFs	**Pelvis mechanism actuated DoFs**	**Other subsystems that provide actuated DoFs**	
Lopes II	3	2	1 (BWS system)	Linear actuator for forward direction (max. force 200N) SEA[2] for the sideways direction (max. force 200N)
PAM	5	5		2 x 3 pneumatic cylinders
NaTUre-Gaits II	5	4 (2x2 robotic arms) + 1 (lateral shift mechanism)		DC[3] brushless motors
Stand Trainer	Customizable (up to 6 DOF)	Customizable (up to 6 DOF)		14 DC motors
WalkTrainer	6	6		DC motors
Lokomat Pro	N/A	N/A	N/A	N/A
ALEX III	4	4		Permanent magnet brushless motors
RGR Trainer	1	1		Servo-tube linear electromagnetic actuator
JARoW-II	3	2	1 (omni-wheels unit of the base frame)	3 AC[4] servomotors 1 brushless DC motor
IBWS	5	5		2 rotary motors 1 linear motor
COWALK	3	3		3 linear actuators (brushless DC motors)
AssistOn-Gait	5	4	1 (BWS system)	SEA
Gait Rehabilitation Robot	3	3		Brushless DC motor
Lower Limb Rehabilitation Robot	2	1	1 (exoskeleton)	Linear actuator DC motor
String-man	6			DC motors
TPMAD	1	1		Maxon Motor

[1]DoF = degree of freedom, [2]SEA = series elastic actuator, [3]DC = direct current, [4]AC = alternative current

Table V

Types of pelvic movements provided by the systems.

System Name	Actuated/Active Movements		Free/Passive Movements		Blocked/Restricted Movements	
	Translation	**Rotation**	**Translation**	**Rotation**	**Translation**	**Rotation**
Lopes II	Medio-lateral Antero posterior		Vertical	Transverse rotation Obliquity Tilt		
PAM	All three	Transverse rotation Obliquity		Tilt		
NaTUre-Gaits II	All three	All three				
Stand Trainer	All three	All three				
WalkTrainer	All three	All three				
Lokomat Pro	Medio-lateral	Transverse rotation	Vertical		Antero-posterior	Tilt Obliquity
ALEX III	All three	Transverse rotation		Obliquity		Tilt
RGR Trainer		Obliquity	All three	Tilt Transverse rotation		
JARoW-II	Medio-lateral Antero posterior	Transverse rotation Tilt	Vertical	Obliquity		
IBWS	All three	Transverse rotation Obliquity		Tilt		
COWALK	Medio-lateral Antero posterior	Transverse rotation	Vertical			Tilt Obliquity
AssistOn-Gait	All three	Transverse rotation Tilt (when not coupled with the mobile base)		Tilt (when coupled with the mobile base)		Obliquity
Gait Rehabilitation Robot	Medio-lateral Vertical	Transverse rotation			Antero-posterior	Tilt Obliquity
Lower Limb Rehabilitation Robot	Medio-lateral Vertical			N/A		
String-man	All three	All three				
TPMAD		Transverse rotation	All three	Tilt Obliquity		

Table VI

Operating modes.

System name	Active (Assistive) Mode			Passive (Non-Assistive) Mode*	Back drivable
	System follows patient and intervenes only if needed	**System follows patient and intervenes throughout the training**	**System is in control and the patient is passively mobilized by the system**	**System follows patient, but does not intervene and the patient moves freely**	
Lopes II			Yes - "Robot in charge" and "Therapist in charge" (selected torques can be applied)	Yes - transparent mode ("Patient in charge")	Yes
PAM			Yes	Yes	Yes
NaTUre-Gaits II			Yes		No
Stand Trainer		Yes		Yes	Yes
WalkTrainer			Yes		No
Lokomat Pro	Yes – "Path control" mode. The system intervenes only if the patient's leg trajectory is outside the virtual torque f eld tunnel	Yes - "Guidance Force" mode between 0 and 100%	Yes - "Guidance Force" mode at 100%	Yes - "Guidance Force" mode at 0	Yes
ALEX III		Yes - "Assistive/Resistive" mode (variable interaction)	Yes - "Locked" mode (inf nite stif ness)	Yes - transparent mode (zero-interaction)	Yes
RGR Trainer			Yes - system in control, during hemiparetic leg swing	Yes - the system is transparent during hemiparetic leg stance phase and healthy leg swing	Yes
JARoW-II		Yes		Yes	Yes
IBWS			Yes		No
COWALK		Actuated legs and actuated pelvis mode	Actuated legs and locked pelvis mode	Free walking mode	Yes
AssistOn-Gait		Yes		Yes	Yes
Gait Rehabilitation Robot			Yes	Yes	Yes
Lower Limb Rehabilitation Robot			Yes	Yes - the system has a device for following the center of gravity	Yes
String-man		Yes		Yes	Yes
TPMAD		Yes			No

Table VII
Center of mass trajectory.

System Name	CoM[1] trajectory of subjects
Lopes II	Allows natural accelerations of the CoM in the vertical axis
PAM	Allows the recording of pelvis movements and has achieved synchronization under the teach-and-replay scheme of normal gait patterns, and therefore CoM trajectories
NaTUre-Gaits	No studies yet, but af ects ground reaction forces
Stand Trainer	CoM control (decrease in pelvic oscillations and decrease in CoP trajectory excursions) in static and dynamic conditions
WalkTrainer	Overall reduction of the motion of CoM
Lokomat Pro	Unnatural due to the restricted motions of the pelvis
ALEX III	Unnatural due to the restricted tilt rotation of the pelvis
RGR Trainer	N/A
JARoW-II	Allows 3D movement of the CoM
IBWS	No studies yet, but reduced ground reaction forces
COWALK	Enables control of the patient's CoM
AssistOn-Gait	N/A
Gait Rehabilitation Robot	N/A
Lower Limb Rehabilitation Robot	Control of CoM in the vertical axis
String-man	N/A
TPMAD	N/A

[1]CoM = center of mass

Gait Rehabilitation Systems Analysis

Type of system, system mechanical components and type of surface

Overground systems and exoskeletons are the most common types of systems that can of er a pelvic mechanism.

Overground systems use the f at surface of the environment (e.g.: room) to train patients, which can lead to a couple of advantages. They are suitable for training of turning manoeuvres, a development that is highly necessary (Pavčič et al., 2014) to avoid obstacles. Also, fall experiments can be performed or exercises on unstable grounds that teach balance (Wang et al., 2011). Applying unexpected perturbations helps study the motor responses of the central nervous system in order to restore balance and prevent fall (Olenšek et al., 2016). All of these trainings and experiments require good control of pelvis motion and of the CoM.

NaTUre-Gaits II, WalkTrainer, JARoW-II and AssistOn-Gait are overground systems that use a mobile base or platform for walking on f at surfaces. Out of the four systems, only JARoW-II does not have a robotic lower limb orthosis or exoskeleton.

With the exoskeleton systems, natural gait patterns can be achieved by using a high number of actuated DoFs. This, however, requires many mechanical parts, which rises the complexity of the mechanism and thus the cost and the weight of the system (Novandy et al., 2009). The heavier the exoskeleton is, the more discomfort the patient feels and the more abnormal the gait patterns become. This vicious cycle results in unsuccessful recovery (Jezernik et al., 2004) if solutions are not found.

Lopes II, Lokomat Pro, ALEX III, RGR Trainer, COWALK and Lower Limb Rehabilitation Robot are treadmill-based exoskeletons that actuate pelvis movements. Lopes II has come up with a solution in respect to the weight problem of exoskeletons. The mechanical part and the actuators are located in a unit behind the patient called "shadow leg" and the patient is connected to this unit with clamps. This way, the patient does not bear the weight of the exoskeleton. Lokomat Pro, ALEX III, COWALK and Lower Limb Rehabilitation Robot, on the other hand, support the entire weight of the exoskeleton with the help of mechanical arms attached to a f xed unit located behind the patient. RGR Trainer's actuation system is gravity compensated as well.

Treadmill-based exoskeletons usually restrict pelvic motions. This can lead to less satisfactory functional outcomes (Guo et al., 2014). Such exoskeletons are Lokomat Pro, Alex III and COWALK. The blocked pelvis movements are described in Table V.

Other treadmill-based systems with pelvis mechanism are pelvic manipulators (such as PAM, IBWS and Gait Rehabilitation Robot) and cable-driven robots or wire-robots (Stand Trainer, which can also work with force plates and String-man).

In the literature there is a debate on the similarity of treadmill walking vs. overground walking. Some studies show that treadmill walking produces dif erent kinematics, while other studies show that treadmill and overground walking produce equal kinematics (Olenšek et al., 2016).

Treadmill-based and footplate-based systems are static. The ground moves under the patient's feet, which is a dif erent stimulation from normal walking. The stimulation of the ground seems indispensable for better outcomes. Overground devices are movable systems. The patient interacts with and travels directly on real ground (Ayad et al., 2019). Although NaTUre-Gaits II is an overground system, it has metallic foot plates between foot and ground and does not allow ground stimulation.

The complexity of overground systems can rise by adding dif erent ground textures or stairs so that the patient can train going up and down (Ayad et al., 2017). All overground systems selected in this review have a mobile base, which limits the training on stairs and some ground textures.

The last system is TPMAD, which is a hip and chest orthosis that can be worn by the patient on any type of surface.

There are two BWS concepts in the literature: the cable-harness BWS (cBWS) concept, when the user wears a harness system, and the structural BWS (sBWS) concept, when the user's BWS is held by a robotic mechanism at waist or back level (Lim et al., 2010). cBWS systems are attached to the suspension mechanism through one single point. This results in lack of control over the direction of the harness when the user tries to walk. However, this can be compensated by the use of a pelvic frame (Mikolajczyk et al., 2018). All the systems in this review have a pelvic mechanism and therefore a degree of control over the direction of the harness.

There are 4 devices out of 16 (ALEX III, RGR Trainer, JARoW-II and TPMAD) that do not have a BWS system and 2 are cable/wire driven robots (Stand Trainer and String-man), meaning that cables can be used to support the body weight of the user. The rest of the systems have either cBWS systems (Lopes II, PAM, WalkTrainer, Lokomat Pro, COWALK and AssistOn-Gait) or sBWS systems (IBWS, Gait Rehabilitation Robot, Lower Limb Rehabilitation Robot). NaTUre-Gaits II is equipped with both sBWS and cBWS systems.

Intention recognition control subsystem and controlled electro-induced contractions

Only one system out of the 16 identif ed has an intention recognition subsystem. WalkTrainer has a closed-loop FES incorporated, named CLEMS (closed loop electrical muscle stimulation), which targets the main muscles responsible for gait: Gluteus Maximus, Vastus Medialis, Vastus Lateralis, Rectus Femoris, Hamstrings, Tibialis Anterior and Gastrocnemius. When the patient tries to move the leg, CLEMS detects the proprioceptive impulses generated by the Golgi apparatus and the neuromuscular spindles of the muscular-tendinous system (Métrailler et al., 2007). Unlike classical FES, which is opened-loop and cannot adapt the stimulation intensity during the execution of movement, CLEMS can, having force sensors placed on the exoskeleton leg, which maximizes the chances for recovery (Stauf er et al., 2009; Métrailler et al., 2007). The force sensors can measure the force and determine the amplitude and position of lower limb segments and therefore, adjust and control the contraction intensity (Stauf er et al., 2009).

Pelvic robot-human interface

The most common pelvic robot-human interface is a pelvic harness, brace or belt, which is in contact with end ef ectors that provide active movement of the pelvis. For cable or wire driven robots, the interface is represented by either a harness or pelvic and trunk belts on which the cables are attached.

The IBWS has a pelvic socket. In order to f rmly f t and attach to the user's particular anatomy, it is designed with six adjustment degrees (Salguero-Beltrán et al., 2012) Although it allows stable body posture with free movement of arms and legs, its structure is rigid (Salguero-Beltrán et al., 2012) and might create discomfort when walking.

Another notable aspect is that there is no perfect harness. All of them induce focal pressure and restrict functional normal gait movements (Mikolajczyk et al., 2018).

Years of f rst and latest research papers

Two of the systems (PAM and String-man) have their latest research in 2007, which might mean they are discontinued. On the other hand, the most recent researches are on Lopes II and Lokomat Pro (2019), Stand Trainer, COWALK and TPMAD (2018). The rest of the systems might be waiting for f nance for upgrades and future research. The most researched system (the number of years spent in research) is Gait Rehabilitation Robot (6 years), followed by Lopes II, PAM, ALEX III, RGR Trainer and COWALK (4 years), while some devices were studied only 1 year (Stand Trainer, JARow-II, IBWS, Lower Limb Rehabilitation Robot and TPMAD).

Allowed human pelvis movements, types of pelvic movements and center of mass trajectory

A number of 6 systems do not allow all six movements of the user's pelvis (Tables III, V). Lokomat Pro and Gait Rehabilitation Robot allow only 3 motions: (mediolateral translation, vertical translation and transverse rotation), the rest of them being restricted. COWALK has tilt and obliquity restricted, while ALEX III and AssistOn-Gait have only one restricted motion: tilt and obliquity, respectively.

There are 4 systems (Lokomat Pro, ALEX III, COWALK, Gait Rehabilitation Robot) which have the most important pelvic motions (lateral translation, transverse rotation and tilt) restricted, while only NaTUre-Gaits II, Stand Trainer and WalkTrainer provide actuation for all 6 movements of the pelvis.

Lopes II, PAM, RGR Trainer JARoW-II, IBWS, String-man and TPMAD actuate some motions, while the rest of them are passive or free. RGR Trainer and TPMAD provide only one active movement, the rest of them being free, and Lopes II and Lokomat Pro provide only 2 active movements.

The trajectory of the center of mass (Table VII) is strongly inf uenced by the restricted motions and also by the free movements of the pelvis if the user has gait dysfunctions. Therefore, theoretically, only NaTUre-Gaits II, Stand Trainer and WalkTrainer are capable of providing the most natural CoM trajectories. However, NaTUre-Gaits II is known to af ect the ground reaction forces and therefore it might inf uence the CoM trajectory as well.

Lopes II, PAM, JARoW-II, COWALK and Lower Limb Rehabilitation Robot partially provide the control of CoM, by reducing the trajectory excursions in some axis.

Pelvis actuation

Traditionally, the interface between an actuator and its load was stif . The advantages for reducing the interface stif ness are lower ref ected inertia, greater shock tolerance, more stable and accurate force control and the capacity for storing energy. A series elastic actuator (SEA) has an elastic component – a spring – that is able to support loads and is not too stif (Pratt & Williamson, 1995). These compliant actuators are designed to reproduce the net human joint torque using the spring during specif c gait sub-phases (Sartori et al., 2015; Shamaei et al., 2013).

The term quasi-stif ness was introduced to represent the relation between torque and joint angles and it does not ref ect the actual stif ness of biological joints (Sartori et al., 2015; Shamaei et al., 2013). Human joint stif ness represents the association of muscle activation and the velocity of its contraction and the elasticity of muscle f bers and tendons (Sartori et al., 2015).

The actuators should reproduce both quasi-stif ness and joint stif ness. The latter is more dif cult to obtain due to the complex modulation at muscle and joint level, while quasi-stif ness can be easily measured using inverse dynamics (Sartori et al., 2015).

Compliant actuator technology is still in its early development (Vanderborght et al., 2013). How compliance is modulated and how it inf uences global stability, it is not yet clear (Qiao & Jindrich, 2016). The answers would help to develop ef ective systems for gait rehabilitation by reproducing typical gait patterns and corresponding ground reaction forces (Torricelli et al., 2016).

WalkTrainer and String-man have 6 actuated DoFs for pelvis movements, while Stand Trainer is customizable and can provide up to 6 active DoFs. PAM, NaTUre-Gaits II, IBWS and AssistOn-Gait have a total of 5 actuated DoFs. RGR Trainer and TPMAD have only 1 actuated DoF and Lower Limb Rehabilitation System provides only 2 active DoFs (Table IV).

WalkTrainer has selective compliance, which means that the physician can decide what DoFs should be made compliant (Stauf er et al., 2009).

Operating modes

In the early stages of rehabilitation, the patient is unable to move a part or all of the lower limb segments, therefore the system should be able to make the movements for the patient. However, after a period of time, the patient might start recovering motor control and the system must be able to adapt and actively assist the patient. This means the patient should start the movement and the system should adjust the trajectory and control the range of motion (Meuleman et al., 2016).

Backdrivability is used to control the force applied by the system on its user, without using force sensors and implementing a feedback loop. Perfect backdrivability is when the torque is 0 (zero-transparency, with no friction or stif ness involved), which is dif cult to achieve, if not impossible. This is why systems that provide high mechanical transparency have high backdrivable actuators, meaning that the mechanical transmission friction and the torques are as close to 0 as possible. This allows the robot to follow the user which moves freely, unconstrained (Gosselin et al., 2016; Koganezawa et al., 2011).

A number of 4 systems are not backdrivable (NaTUre-Gaits II, WalkTrainer, IBWS and TPMAD), and 5 systems (Stand Trainer, JARoW-II, AssistOn-Gait, String-man and TPMAD) do not provide the operating mode in which the robot is in control and the user follows the robot passively. There are 8 systems which are capable of following the patient and intervening throughout the entire training session, even if not needed (Stand Trainer, Lokomat Pro, ALEX III, JARoW-II, COWALK, AssistOn-Gait, String-man and TPMAD), and only one system (Lokomat Pro) has an operating mode in which the robot intervenes only if needed, when the patient's leg trajectory passes outside the virtual torque f eld tunnel (Table VI).

Conclusions

1. The main objective of the gait rehabilitation systems is to help patients achieve the highest possible level of functional independence, given their situation.

2. Future research directions for system improvements should consider motion intention recognition systems based on brain computer interface, FES, EEG or other technologies that can be applied in a closed biofeedback loop, in order to predict and assist the patients' movements and adjust their trajectory and range of motion only if needed. It would make a huge dif erence if it can be implemented for assisting the pelvis, as well as the impaired lower limb.

3. Other challenges address the backdrivability and control system that should be able to compensate the device's inertial ef ects and therefore, synchronize automatically the device's motion with the user's motion.

4. Regarding the harness, although there is no perfect harness, it can be equipped with pressure sensors to establish the degree of pressure and help the patient relieve it, by making adjustments.

5. Future research is needed to conclude whether treadmill kinematics are dif erent from overground kinematics.

6. Future objectives should include the increase of the addressability of these gait rehabilitation systems in order to cover more complex gait disabilities generated by diverse pathologies. This can be achieved by giving up on the mobile base of overground systems and coming up with a better mechanical solution that can enable the patient to train in more complex environments, such as dif erent ground textures or stairs.

Conf icts of interests

Nothing to declare.

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Pedagogical considerations regarding the structure of high school upper cycle syllabuses, for the "Theoretical Sports Training" school subject (Note II)

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Abstract

The outcome which appeared from the analysis of the syllabuses for "Theoretical Sports Training" in the high school upper cycle identif ed inconsistencies between the specif c competences and the associated contents. In order to give a resolution to these specif c problems, specif c proposals of improvement which were able to create a logical rapport between the structural elements of the syllabus, for both 11th and 12th grade were elaborated. This (re)setting, on more logical coordinates from the curriculum standpoint, leads to a rigorous design of contents of the school subject, which would make the teaching process more ef ective, and would direct the subjects' mindset towards higher cognitive behaviors and superior emotional attitudes.

Keywords: high school upper cycle syllabuses, "Theoretical Sports Training" school subject, general and specif c competences, teaching contents.

Introduction

The National Council for the Curriculum started up the curriculum reform for the "Theoretical Sports Training" school subject (TST) in 2000, when it elaborated a "Methodological Guide for the implementation of syllabuses" for all high school classes, sports program (***, 2000). However, it was only in 2006 that the f rst analytical programs for the upper high school cycle appeared on the curricular scene (1), (2).

School curricula are structured on specif c competences for each year of study (11th grade and 12th grade), derived from the six general competences, numbered with digits from 1 to 6. Each specif c competence has the serial number which corresponds to the general competence from which it derives (1.2., 2.1., 3.3., 4.1., 5.1., 6.1., etc.). For example, from the 3rd general competence, "3. Operating with theoretical and methodological elements specif c to sports training", in the 11th grade, two specif c skills derive: "3.1. Systematization of the contents of the components of theoretical sports training" and "3.2. Justif cation of the use of the main selection criteria in the practiced sporting discipline".

In the 12th grade, the specif c competences deriving from the 3rd general competence are: "3.1. Identifying the factors that determine one's f tness level" and "3.2. Developing of the main planning documents specif c to theoretical sports training". The specif c competence number deriving from a general competence can be the same for both levels of schooling (11th grade / 12th grade) or dif erent, depending on the complexity of the school curriculum contents. Thus, in the 11th grade, from the 6th general competence ("6. Organization of schooling and competition activities, in accordance with the regulations in the f eld and with the attributions of the sports trainer"), a single specif c competence derives (6.1.), and in the 12th grade, two specif c competences derive (6.1., 6.2.).

These syllabuses have opened a new perspective in planning and managing the teaching process, by providing teachers with a real support, based on choosing and using proper teaching strategies according to the psychomotor features of the trained subjects and to the rigors of practicing performance in sport (Sandler & Kamis, 1984; Allen & Simpson, 2019).

With all the inherent shortcomings of any start up, these curriculum components have the merit (which cannot be denied) to promote an active education, giving the teacher the opportunity to shape students' personality and to adjust their natural bent, from a cognitive and psychomotor perspective (Berdrow & Evers, 2011; Hrivnak, 2019).

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The analytical programs for the 11th and 12th grade submit contents that would lead to forming superior cognitive skills and could create those rational and motivational states of mind that are needed for every subject who practices performance in sport, in order to validate his/ her creative abilities in regard with the requirements of the specific sports branch, with his/ her own interests and intellectual yearnings (Lee & Gopinathan, 2012; Abbiss, 2018; Kim et al., 2018).

Every syllabus must (or should) be based on the logic of the school subject being taught, taking into account the fact that the distribution of knowledge should be centered around the fundamental logic of that particular science, insisting on the most significant theses and principles for understanding all the other phenomena. Only if the teachers can easily use these flexible and attractive curriculum tools which are compulsory for the teaching process and the syllabuses, would the loss of context and meaning of a knowledge element from that specific science be avoided (Nicola, 1994; Priestley, 2011; Biesta et al., 2015).

If nowadays the main problems with most of the school subjects are related to the easing of programs, these shortcomings fall to a secondary plane in the case of the TST school subject. The analysis of these curriculum papers has outlined a series of inconsistencies between their structural elements, which could influence in a negative way both the quality of the teaching process and the level of development for the targeted competences. After a relatively large number of years since the appearance of the syllabuses for the TST school subject, the upper high school cycle, in the curriculum domain, the discussions should have gone beyond the "comfort zone" of the topic that aims at a balance of specific skills and their associated contents (Alton-Lee, 2011; Harris & Burn, 2011; Christopher et al., 2017; Stewart, 2018). At present, other types of "critical drills" ought to be in the spotlight, much more demanding things, which would give substance and credibility to the school subject, such as: to create, within the curriculum, a coherence between the school syllabuses, both vertically and horizontally, or to search some reforming strategies that could outline the contents of the programs in order to strengthen the process of learning and to create logical, flexible, original and critical thinking of the subjects (Blasco, 2012; Mutch, 2012; Singer, 2013; Rodríguez-García & Arias-Gago, 2020).

Material and methods

The goal of the research is to analyze the syllabuses for the TST school subject, the high school upper cycle, sports profile, vocational education. In this matter, the following *objectives* were established:

- to analyze and identify possible dysfunctions in the structure of the current syllabuses of the 11th and 12th grade;
- to outline some proposals that would balance the structural coherence of the syllabuses, considering the final products pursued at the end of the high school cycle.

The used *methods of research* were: the bibliographical documentation method and the analysis of the teaching-learning process documents.

Results

The analysis of the 11th grade syllabus

The specific competence "3.1. Contents systematization of the sport training components" and its corresponding contents (physical training, tactical training, technical training, theoretical training, psychological preparation) are similar to a 10th grade syllabus competence ("2.1 The use of contents specific to sports training components"), and the same contents as well as the level of preparation already mentioned are reflected (physical training, technical training, tactical training, psychological preparation, theory and method practice) (3).

As a paradox, the general skills of the specific issues presented are different. Thus, if for the 10th grade, the specific competence derives from the second general competence ("The use of specific terminology in sports performance"), for the 11th grade it derives from the third general competence ("Operating with theoretical and methodological elements which are specific to sports training").

The competence "3.2. The rationale for the use of the main selection criteria in the practiced sports discipline" - regarding selection in sport aims the contents from which the learning unit that best reflects the argument of using the main selection criteria for the practiced sport type is missing: *designing the pattern lesson*.

The specific competence "5.1. To measure the level of development of aerobic resistance, in terms of evaluation" presents some inaccuracies, compared to the syllabus content units. The competence highlights only one resistance form - "aerobic resistance", and the other forms of resistance are not to be found in the curriculum. Another inconvenience is that, considering the curriculum content, the contents and learning units that would further develop this movement quality prior to evaluation are not specified, and the evaluation stated in the syllabus competence makes strict/explicit reference to the assessment of aerobic resistance.

The analysis of the 12th grade syllabus

The contents associated with the specific competence "3.1. The identification of objective factors that condition the sports form" are not fully represented. Due to the fact that the syllabus refers directly to the objective factors, the other conceptual and methodological aspects of major importance in sports training are omitted (the subjective factors of the sport form, the cyclic nature of the sport form, the staging of training). Of the content units of the sports training structure, the training lesson as a basic structural unit is missing.

The specific competence "4.1. Elaborating the practice plan of a micro-cycle during competition times" does not reflect in any way the contents that make reference to the "relationship between training - competition - recovery".

Moreover, the contents of the syllabus (the "relationship between training - competition - recovery") are not in accordance with the corresponding learning units ("singular competition", "series of competitions", "qualifications", "tournament"). The previously specified training units are, in fact, specific to the syllabus contents which targets the "competition system, types of activities" and "contest scheduling", and which corresponds to the specific competence “6.2. Team organizing of a competition at high school level”.

Similar to the previous competence, the specif c competence “4.2. Designing a training lesson plan/ project” exposes a serious dissension regarding its contents. Thus, the content ref ects *the sports training lesson* (in terms of pattern and structure) and not “drawing up a sports training lesson/ project”. *The sports training lesson*, as a learning unit, should be placed in the contents of the sports training structure.

To sum up, the specif c competence and its learning unit contents, in a subordinate relation to the specif c competence “3.2. To draw up the main planning documents specif c to sports training”, should not be found in the syllabus, as the following specif c competence “Assessing sports training valences in special natural conditions” is subsequently to be 4.2.

Following the same analytical line, the specif c competence “5.1. Establishing the ef ciency level of technical-tactical drills, in order to be assessed” presents some inaccuracies. Due to the fact that in sports training, the level of technical-tactical preparation is not the only one evaluated, some conceptual inaccuracies were traced throughout this competence and its contents.

Due to the fact that the 5th general competence presented in the curriculum, “Appropriate use of methods and techniques specif c to investigation, interpretation and evaluation/ self-evaluation sports training levels”, refers directly to the motricity index, which is “distributed” in each year of study, in the current syllabus of the 12th grade, the specif c competences and their contents related to the coordinating skills, mainly mobility and f exibility, were overlooked.

Discussions

The results from the undertaken analysis are likely to allow us to submit proposals that would lead to a more transparent approach of the contents, in relation to the problems highlighted at the level of the competences in the syllabuses for the high school superior cycle.

The 11th grade

The specif c competence 3.1.

It is necessary to design a specif c competence that would replace the current one from the syllabus, as follows: “3.1 Structuring the sports training content through dif erent stages of practice”, and to add some new contents and learning units that would ref ect the newly stated competence, such as:

The staged character of sports training:

- *stage I of training - oriented basic training, according to each type of sport (OBT);*

- *stage II of training - specialized constructive training (SCT);*

- *stage III of training - high performance oriented training (HPOT);*

- *stage IV of training - high performance training (HPT).*

The specif c competence 3.2

Completing the contents with a new learning unit; together with “the selection system” and “selection criteria”, the “*selection pattern*” should also be found.

The specif c competence 5.1

The subsequent data to be added require:

- to design a specif c competence that would replace the existing one, for instance: *5.1. Establishing, for evaluation, the resistance development level within the practiced sport discipline*;

- to add new contents and learning units to the present syllabus, which could fully ref ect the newly designed specif c competence: endurance - *endurance types, conditioning factors, endurance development methodology;*

- to replace the curriculum content which refers to methods and techniques to measure aerobic endurance, with *methods and techniques for endurance tests.*

The 12th grade

The specif c competence 3.1:

- to design a new specif c competence that would replace the existing one, for example: *3.1. Objective evaluation of your own training and f tness evolution*;

- to outline the contents and learning units which are specif c to the newly designed specif c competence, such as:

– f tness shape (the objective and subjective factors of the f tness shape, the cyclic nature of the f tness shape);

– training staging (preparatory period, competitive period, transition period).

- to develop a specif c competence for contents that aim the structure of sports training and the training lesson suitable for inclusion in the content of the syllabus.

The specif c competence 4.1:

- to design a new specif c competence that would ref ect the contents from the syllabus, as in the example: *4.1. Measuring the existing connections between training, competition/ contest and recovery within the practiced sports school subject.*

- to outline new learning units that would ref ect the newly designed competence, such as:

– *training and competition;*

– *training - competition - recovery relation.*

The specif c competence 5.1:

- to design a specif c competence that incorporates the whole assessing concept and to replace the current one, such as: *5.1.Evaluating the level of training and performance achieved within the practiced sports discipline*;

- to specify new contents and learning units for the newly designed specif c competence, such as: *evaluation criteria - assessing: types of evaluation, tests in order to assess movement skills, specif c to the practiced sports discipline*.

The specif c competence 5.2:

In the current 12th grade syllabus, the specif c competences and contents related to the coordinating capacities are missing, specif cally mobility and suppleness. This inconvenience could be solved by designing new specif c competences and contents for each of the two movement skills omitted in the current syllabus.

Subsequently, for the coordination abilities:

- the newly designed specif c competence will be assigned the number *5.2.* and will be entitled: *Determining, for the purposes of evaluation, the level of development of the coordinating abilities in the practiced sports discipline*;

- the contents of the newly designed competences will aim:

– the coordinating skills: forms of manifestation, the components of the coordinating abilities, the factors that condition the coordination abilities, the methodology of the coordinating skill development;

– the assessment of coordinating abilities: tools, tests, trials.

The designed specif c competence for mobility and suppleness will be assigned the number *5.3.*:

- *5.3*: *To establish, for evaluation, the development level of mobility and suppleness in the practiced sports discipline/ school subject;*

- the contents related to the newly designed specif c competence will aim:

– mobility and suppleness: disclosure forms, factors that inf uence mobility and suppleness, the methodology of mobility and suppleness development;

– mobility and suppleness assessment: tools, tests, trials.

Conclusions

The analysis of the syllabuses and curriculum for the high school upper cycle, 11th and 12th grades, outlined the following conclusions:

1. Not all the specif c competences have ref ections in their contents. There are occurrences when a content submitted in the syllabus is reused in the syllabus of the following year, aiming for other objectives and competences.

2. The scientif c content of the syllabuses is not organized step by step. Therefore, it can be reached for tasks with serious complex accents that are intended only for a certain type of students, the rest being overwhelmed by the amount and quality of information which they should have processed.

3. The syllabuses target only the intrinsically learning motivated students, who are able to process abstract information at a constant pace throughout the school year.

4. Not all contents prove scientif c rigor, cultural relevance and up-to-date information. If some contents have a highly motivational value, submitting knowledge that is able to trigger and sustain the epistemic and cultural motivation of students, the taste for study and the expansion of the knowledge horizon, other contents are unappealing.

The syllabuses must be the main “psycho-pedagogical binder” between the teacher’s skills and the subjects’ abilities. The constant balance of the structural elements in these curriculum frameworks should remain an open topic that would concern all the engaged factors in the ef ectiveness of the teaching process.

Conf icts of interests

There are no conf icts of interests in this study.

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Adapting the motor behavior of the judoka in the formative stage of performance

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Abstract

This study is a meta-analysis of the concept of motor behavior in judo, addressed during the formative stage of performance discussed in the international and Romanian literature: the components of motor behavior, the stimuli used during training regarding the possibilities of optimizing motor behavior in judo, regulation and self-regulation as factors for improving performance in judo.

The issue of the progressive optimization of training stimuli, which are represented by the factors of training (volume, intensity, complexity-density), as well as that of motor, medical and psychological criteria, applied during training by methods and procedures specif c to judo, is addressed.

To obtain high performance, the coach together with the team of specialists should act on the mentioned levers, through specif c training methods, as well as by investigating and monitoring their level. High-intensity ef ort is stress for the judoka, and athletes must continuously adapt by special and repeated training. In order for this adaptation to occur, during training, increasing intensity stimuli will be used, until stimuli close or identical to those used in competition are obtained.

Keywords: motor behavior, judo, training stimuli, adaptation.

Particularities of motor behavior in judo, in the formative stage of performance

We consider the formative stage of performance the post-puberty/adolescence age (15-18 years). At this age, the motor behavior of judoka is relatively little studied in the international and Romanian literature. The optimization of motor behavior refers to the following: the technical and physical training system for junior judoka IV, III and II (U-18, U-16 and U-15); the biomotor abilities required to obtain performance – strength and resistance of the trunk muscles, particularly *lumbar, scapulohumeral girdle and forearm and palmar f exor* strength, which would allow the judoka to increase their capacity to generate and maintain force during the f ght; reaction and execution speed, explosive force, motor coordination resistance, focused attention.

Optimizing motor behavior involves improving the main requirements of judo: those of neuromuscular and neuropsychic nature such as kinesthesia (the capacity to sense the movement of various parts of the body), coordination/dexterity, attention focusing capacity, reaction speed, explosive force (push-ups and plyometric jumps, hitting the medicine ball with one hand, throwing the medicine ball from the chest, jump squats), requirements that currently have a relatively low level, which inf uences the competition results.

The high level of coordination, as a component of motor behavior, is the premise for ef ective learning of new technical elements, and abilities and coordination determine the way in which a judoka f ghts (Czajkowski, 2004).

Judo is a sport characterized by many specif c technical procedures and a variety of exercises practiced under exceptional conditions. The movements of judoka should be rapid and suf ciently precise to ensure the ef ectiveness of the f ghting technique used. Consequently, judo is considered as the sport with the highest level of coordination and complexity (Hirtz & Starosta, 1991; Starosta, 2003; Starosta, 2006).

Technical and tactical training in judo involves preparing all technical procedures and forming skills and abilities according to the athlete's motor abilities (Hantău, 1996). At relatively early ages (14-15 years), when work for improving the technique intensif es, training should be largely aimed at developing the general and specif c motor skills, so that the judoka can acquire a correct technique of the technical procedures, Nage-Waza components and Ne-Waza components (Vodă & Pop, 2008).

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In studies conducted in groups of junior judoka (U 18), it was found that the activity of subjects during personal attack phases was correlated with their abilities to dif erentiate movements and speed, as well as with the accuracy and precision of movements, while the reaction time was correlated with the level of sports achievement (Lech et al., 2011; Lech et al., 2014). Other studies demonstrated that higher performance in cadet tournaments (juniors under 18 years of age) signif cantly depends on the strength and resistance of the cadet/junior (Krstulović et al., 2005).

Individual aspects of coordination might af ect the course of the entire attack, as well as phase I and II; consequently, coordination can determine the level of performance of the competitors. Despite the importance of motor coordination, this determining component of success in judo has been little investigated in studies related to judo. The aspects of coordination as a result of fatigue (Lima et al., 2004) and its relationship with other sports abilities (Hrysomallis, 2011) are studied even less. In the literature on judo, a number of publications present data referring to the levels of *aerobic and anaerobic capacity* (Little, 1991; Borkowski et al., 2001; Thomas et al., 1989), *resistance* (Iwai et al., 2008) and *the constitutional biotype* (*body type*) (Franchini et al., 2007) of judoka, as well as their importance in obtaining success.

Competition judo is a high-intensity sport, in which athletes unbalance each other permanently, while executing dif erent techniques (Yoshitomi et al., 2006; Perrot et al., 1998; Perrin et al., 2002). These continuous and dynamic changes in balance are part of a dynamic system in which two judoka, benef ciaries of a rich technical and tactical repertoire, having abilities specif c to the age and weight category, use this repertoire and always create attacks, defensive actions and counterattacks (Sertić et al., 2009; Sterkowicz et al., 1997; Sterkowicz & Maslej, 1998; Franchini et al., 2008; Sertić, 2004).

In judo, the two f ghters come close to each other, execute the holds, move on the tatami, and attack. The approaches and kumi-kata (hold technique) allow specif c behaviors between the two competitors. The duration and capacity of simultaneous actions, the multitude of interactions and the f nal result lead to a complex system, which is most frequently established by the coach and the competitor. A computerized record can help to evidence actions associated with success in this complex system (Calmet et al., 2010).

During a judo f ght, the athletes aim to throw their opponent to the ground or to obtain control during the ground f ght. For example, technical and tactical behaviors are essential for attacks and combinations of tasks in dif erent situations, required for the application of the techniques (Franchini et al., 2008). To project an opponent, a judoka must get close to him/her. Consequently, the attacker adopts various interactive behaviors, adapted to his/her opponent (Castarlenas & Planas, 1997).

The muscular ef ort during a f ght is combined, both dynamic and static, but the dynamic ef ort prevails over the static one, being represented by explosive executions and moves (Little, 1991; Kubo et al., 2006; Heitkamp et al., 2002; Sertić et al., 2007). Judo as a sport is a specif c model of physical activity with high demands on the psychosomatic state of the athletes. During training and competition, almost all psychosomatic systems of the judoka function in the submaximal and maximal exercise areas (Sertić et al., 2009; Parmigiani et al., 2006).

Psychosomatic medicine is an interdisciplinary medical f eld that explores the relationships between the social, psychological and behavioral factors of the body processes and quality of life in humans and animals or, in other words, the relationship between the body and the mind.

Physical exercise, particularly maximal and submaximal exercise, performed during training and competition, represents stress that acts on the athlete's mind during training as well as in competition.

Learning to manage this stress during competition or training, when maximal and submaximal exercise is performed, is extremely important for athletes. Otherwise, they are prone to become victims of these functions, with the diminution of performance, which will be negatively inf uenced by mental, psychosomatic factors such as stress and anxiety (Yoshihara & Kubo, 2009). Judo is a complex sport, with requirements comprising a number of specif c characteristics, needed to reach a high level in competition. Upper and lower body strength and resistance, speed, anaerobic power and trunk muscle function were evidenced as important factors in obtaining success during judo competition (Iwai et al., 2008; Franchini ș.c., 2011; Muraru, 2008).

In a classif cation of sports performed by Gandelsman and Smirnov in 1970, assigning sports to 7 groups, which is still valid today, judo is part of the fourth group that includes all team sports and individual sports with direct opponents – contact sports (boxing, wrestling, judo, fencing). The necessary skills are an excellent functioning of senses and the ability to perceive and act under continuously changing competition conditions. The decisions made in a complex f ght situation depend on the athlete's ability to sense the external stimuli, which allow the athlete to interact with the opponent at dif erent levels. The rapidity and precision of the interpretation can prevent the opponent from executing a successful tactical move or can bring success (Bompa, 2002).

Regarding the trunk muscle function, the improvement of the strength and resistance of these muscles would allow the judoka to increase their capacity to generate and maintain force during a f ght. Furthermore, basic stability can contribute to judo performance, because it would facilitate the transmission of the forces generated by the lower limbs to the trunk (and vice versa) (Kibler et al., 2006) during judo techniques and would improve balance control (van Dieen et al., 2012), a key factor in counteracting the unbalances caused by the opponent (Yoshitomi et al., 2006; Perrot et al., 1998; Perrin et al., 2002).

The requirements in judo (neuromuscular and neuropsychic) are the following: kinesthesia (the ability to sense the movement of various parts of the body), native intelligence, dexterity, attention focusing capacity, reaction speed, explosive force (hitting the medicine ball with one hand, throwing the medicine ball from the chest, jump squats, "frog leaps", lateral jumps over hurdles) (Toacă, 2002).

According to Ioan-Enne (1), competitive judo has the following characteristics: it is a confrontation of two personalities, with dif erent skills, temperaments and f ghting styles; the opponents change frequently, in a relatively short time; a direct dispute takes place, at a relatively small distance, in which the two opponents study their intentions and moves, trying to counter them using a wide range of technical and tactical means; rapid and unpredictable changes occur in the technical actions and in the tactical thinking of both opponents during a match or an action.

The factors of performance in judo according to Ioan-Ene (1), ref ected in the current scientif c and methodical literature, taken into consideration when drawing up the descriptive chart to establish the *psychological prof le of the judoka,* and the selected mental qualities pertaining to these factors are shown in Table I.

Table I
Determination of the psychological prof le of a successful judoka (1).

Motor ability	Mental ability	Somatic type
45%	40%	l5%
Dexterity	Mental qualities - Intellectual factor - attention - creativity (operational thinking) - rapid decision (anticipation-intuition - memory - imagination	Height
40%	45%	40%
Strength-Speed	Mental qualitites - Volitional factor - courage (boldness) - determination (activism) - initiative - perseverance	Length of the limbs
40%	30%	35%
Resistance	Mental qualities - Emotional factor - emotional stability - vigilance (responsibility) - commitment	Height/weight
20%	25%	25%

The psychological prof le of a successful judoka is a projection of the human psyche, a complex, dif cult to verify process, which should however be included in the sphere of the *perspective plan* (Table I).

Studies in the f eld of motor behavior in judo

Research in judo dates back to the beginning of the past century, the trends in judo being expressed by J Kano's slogan: *Maximum ef ciency with minimum ef ort* (2).

Over the last 30 years, researchers in dif erent countries have demonstrated that one of the most important factors for the development of technique and tactical excellence in judo as well as in other wrestling or team sports is coordination (Blume, 1978; Starosta, 2003). Coordination and its role in motor behavior were also studied by Czajkowski (2004), Hirtz & Starosta (1991), Starosta (2006). Some studies focused on the importance and role of strength and resistance in juniors (Krstulović et al., 2005). Lima et al. (2004) and Hrysomallis (2011) studied aspects of coordination under fatigue conditions.

Some other studies published abroad focused on aerobic and anaerobic exercise capacity (Little, 1991; Borkowski et al., 2001; Thomas et al., 1989), resistance (Iwai et al., 2008) and the constitutional biotype (body type) (Franchini et al., 2007).

Some authors took scientif c interest in the procedures and their technique for improving balance control, a key factor in f ghting the unbalances caused by the opponent: Perrot et al.,1998; Perrin et al., 2002; Yoshitomi et al., 2006.

In Romania, reference fundamental or applicative scientif c studies related to sport in general, motor behavior and human performance, neuromuscular and neuropsychic aspects or judo were conducted by: Epuran, 2001; Bompa, 2002; Dragnea & Teodorescu, 2002; Epuran, 2005; Hillerin et al., 2015; Marin et al., 2015; Botezatu et al., 2015.

In our country, in the area of judo - motor behavior, research was carried out on the following subjects specif c to judo, focusing on the following topics referring to the forms of training and functions specif c to this sport: *technical and methodical training* (Hantău, 1996; Hantău & Bocioacă, 1998; Bocioacă, 2007; Vodă & Pop, 2008; Pop, 2010; Robolu, 2014b); *technical training* (Hantău & Bocioacă, 1998; Bordea, 2000; Pop, 2010; Frazzei, 2014); *methodical training* (Muraru, 1975; Stefănuţ, 1983; Hantău, 2000; Pălărie, 2003; Chelaru, 2010; Răchită, 2011; Robolu, 2014a; Robolu, 2014c); *physical training, development of motor skills* (Hantău & Bocioacă, 1998; Bocioacă, 2003; Pop & Pop, 2007; Giurgiuveanu, 2014; Robolu, 2014a) and *improvement of balance function* (Răchită, 2011); *psychological training* (Roşu et al., 2006; Sava, 2014); *biomechanics of procedures in judo* (Răchită, 2011; Pop, 2012); *selection in judo* (Stefănuţ, 1983; Chelaru, 2010; Robolu, 2014b).

Analysis of motor behavior specif c to judo

The components of human motor behavior are: movements (change of the body position in time and space), acts, actions, activities, movement, which are considered as an organization of behavior depending on certain purposes and are supported by motivation (Epuran, 2005, 266).

When analyzing behavior in high performance sport, the accuracy of a technical gesture or element, the problem of correctly training specif c skills, as well as the possibility of improving their ef cacy emerges (Epuran, 2005). Hence, the need for correct acquisition of the basic technique of technical procedures in judo in order to avoid subsequent time allocation during training to correct the technical errors.

Motricity and movement are basic terms in the theory of body activities (Table II).

Table II
Classif cation of fundamental movements (Dauer et al., 1986; Gallahue, 1993; Siedentop et al., 1984, quoted by Epuran, 2005).

Locomotor movements	Manipulation movements	Stability movements
Walking	Throwing	Leaning forward
Running	Catching	Reaching out
Jumping	Hitting	Twisting
Bouncing	Blocking	Turning
Tramping	Striking	Swinging
Dragging	Volleying	Rolling
Sliding	Leading	Landing
Climbing	Rolling (of a ball)	Stopping
Lunging	Carrying	Dodging
Galloping	Dribbling	Balancing
Bobbing		

It is the teacher (coach) who monitors the achievement of motor acts, builds them and evaluates them based on a number of criteria (Epuran, 2005, 273).

According to some researchers, behaviors fit into two categories: *adaptive* behaviors, which are those observable and measurable reactions/responses learned during ontogenetic development that are useful to a person and help that person efficiently adapt to the environment; *disadaptive* behaviors, which are those observable and measurable reactions/responses learned during ontogenetic development that are detrimental to a person and prevent that person from efficiently adapting to the environment. A behavior is not adaptive or disadaptive per se; it becomes adaptive or disadaptive only in relation to a certain context (David, 2016).

Mental processes such as imagination, thinking and memory significantly contribute to the training and improvement of an athlete, forming and changing the behavior of the athlete (judoka in our case).

The behavior of a high performance athlete also varies depending on the personality of the coach and on the objectives set by him/her in the training plan. Stimuli also play an extremely important role in the behavioral-sporting manifestation and significantly influence the athlete's behavior. The rules of sports are other factors that contribute to the behavioral development of athletes. Technique and tactics are elements that define the individual behavior of athletes. Stimuli (requests during training) are muscular, cardiorespiratory, neuroendocrine-metabolic, psychic, physical exercise with its parameters, motor (technical) actions, etc.

At the opposite pole are non-sporting, deviant behaviors, which also contribute to the behavioral portrait of a high performance athlete. The practiced sport influences both the athlete's character and behavior. For example, athletes having practiced a team sport more easily integrate in the social environment, are more flexible and open to collaboration and successfully work in larger groups of people. There are individuals who have a harder, firmer behavior, in which a slightly excessive attitudinal rigor can be seen in relation to the rest of the surrounding persons, who did not practice high performance sport. This type of behavior is influenced by the rules and the particularity of individual sport, especially in those sports where there is direct contact with the opponent (e.g. judo) (Ciurea, 2017).

Motor behavior in judo is directly influenced by the program attended during training: inclusion of adequately dosed and individualized exercises for the development of strength in the extensor muscles of the knee joints, trunk flexors and rotators. As a result of using the selected specific and non-specific means, aimed at the acquisition of throwing over the hip procedures, good results were obtained regarding: the optimization of motor skills and abilities; the development of specific muscle groups, which shortly contributed to the correct acquisition of the procedures (Sava & Panaitescu, 2016).

An important role in the acquisition and development of skills by training is played by the coach or instructor starting from young ages, up to older ages. The way in which the intervention is performed during training by introducing the new techniques and procedures in order to acquire new skills is by focusing on the individual characteristics taking into account the existing knowledge in the field, which provides a new approach to training (DeMars & Pedro, 2013). Thus, a new training program is created, which is based on the current requirements and trends in the development of wrestling sports, and in this way, the degree of adaptability to physical and mental exercise, the level of personal safety and self-confidence increase (Pop & Pop, 2007).

The theoretical basis of behavioral change by the system of reinforcements and punishments represents the mechanism of operant conditioning, studied by some outstanding representatives of the behavioral school (Thorndike, Tolman, Guthrie, quoted by Dafinoiu, 1999). They discovered that if a certain behavior is consistently followed by reward, the behavior is more likely to reoccur.

The most accessible, easy to observe and identify personality traits are the temperamental ones. They refer to the energy level of action. Descriptive adjectives: energetic, explosive, resistant, expansive, rapid, slow, and their antonyms (Dafinoiu, 1999). Temperament refers to the energetic-dynamic dimension of personality and is expressed both by particularities of intellectual activity and affectivity and by external behavior (motricity and speech).

Cosmovici (1999) mentions attention as an orientation and concentration of mental and cognitive activity on an object or process, in agreement with Toacă (2002), which mentions the importance of attention, particularly its focusing capacity, among the requirements of judo. This mental process is strongly influenced by motivation, emotional states, being accompanied by well-known characteristics of posture and mimics.

In motor learning, memory has a determining role. Memory is the basis of both cognitive and motor learning. Motor learning is aimed at the acquisition of motor abilities and behaviors. It requires the control of energy sources and the specific use of analyzers. For the training of motor abilities, the acquisition of knowledge is not the purpose, but the means by which training is achieved, cognitive learning being a functional process for the motor solution, and not its objective (Schnidt 1982, Weineck 1982, quoted by Hanțiu, 1993).

The specific movements of sports or sport branches are part of their technique. Learning them, consequently learning the technique, obeys the rules of motor learning.

An extremely important principle that should be taken into consideration during training is the *correct acquisition of the technical procedures of judo, which represents a fundamental task of the coach during the first stage of training, with major repercussions in the subsequent training stages*. The technical procedures are special motor skills, by means of which the judoka performs judo specific actions with maximum efficiency (Dragnea et al., 2006).

Continuing the ideas above, we consider that paying greater attention to correct learning of the basic judo technique is required from the teachers-coaches who initiate athletes to the practice of judo, even if this involves delaying the participation of these categories of juniors in multiple competitions in order to win medals at any cost. New technical procedures (skills and abilities) should be trained, with emphasis on a correct basic technique and then the formation of a personal style depending on the athlete's biopsychomotor particularities, especially the temperamental predominance of each athlete. Technical errors should be avoided, because a lot of training is required subsequently for their correction.

Motor competences involve the fluency and control of the body muscle movements. This includes gross or basic motricity, exerted by the muscle groups (e.g.: "to start", "to stop", "to turn around", "to climb") and fine motricity (e.g.: "facial expressions", "finger dexterity", etc.). Motor competences are extremely important for the investigation of the environment and the acquisition of new knowledge (Miclea et al., 2010).

An emotionally balanced athlete contributes to the control of his/her own behavior in limit situations (high-level competitions, tense training sessions, disturbing administrative, financial, health-related factors, etc.). Emotional balance depends on emotional maturity, which in turns depends on the heredity of the person concerned and on the environment in which that person develops (the family in particular). Emotional balance also manifests by mobility/dynamics depending on the situation, therefore moderate mobility, while emotional imbalance appears as both too great mobility (fluctuation, transition from one mood to another without any reason) and too reduced mobility (emotional perseverance).

The result of an important competition can be decisively influenced by emotional moods generated by various factors, some of which can frequently be not attributed to the coach (transport/meal/accommodation conditions, tension in the relationship with the friends/family, etc.). Training can be affected by such causes, for which the coach should find solutions (identification-recognition-solution) through sincere, well-balanced communication with the entire group or only with those concerned.

The coach has the task to keep informed about everything that is important in the life of the athletes with whom he/she works (family, school, hobbies, favorite movie characters, etc.) in order to act, adjusting his/her own behavior, using all his/her skills (authority and professional competence, personal charm, humor, etc.) when needed and then, to induce by contagion the optimal emotional state for training and competition.

Biomedical particularities of judo depending on the training stimuli applied

The factors of training in general, and in judo in particular, are the following: volume, intensity and complexity (density), which are the levers used in the regulation of the parameters of exercise, for the development of specific motor skills. We also mention that a complete training process is based on three main criteria: motor, biomedical and psychological. To obtain high performance, the coach together with the team of specialists must act on the mentioned levers, by methods and means specific to judo. Intense and high-intensity exercise, as previously mentioned, is stress for the athlete, for the judoka, respectively. The judoka must adapt to this inevitable high-intensity stress and cope with it by special and repeated training. For this, as part of training, increasingly intense motor, biomedical and psychological stimuli will be used, until stimuli close or identical to those of competitive activity, including stress factors, are obtained. It is known that judo is a sport of explosive force, of strength-speed, muscle resistance, combined with an apparently latent phase of unbalancing the opponent and avoiding to be unbalanced by the opponent.

According to some authors, sports can be classified into 9 categories, according to the type of physical exercise performed (Tache & Staicu, 2010). Judo fits in three of these categories (types), alongside other sports, in which the same type of effort occurs.

- Sports with special cardiac demand and apnea: swimming, athletics – sprint running, fencing, gymnastics, weightlifting, *judo*, wrestling, alpine skiing, tennis and table tennis, underwater sports, yachting (Talbot 1975, quoted by Epuran et al. 2001).

- Mixed-effort sports: games; boxing; tennis and table tennis; Greco-Roman and free wrestling; *judo*; handball; biathlon; motoring; badminton; horse riding; rowing; sports gymnastics; ice hockey; motorcycling; speed skating; rugby (Tache & Galea, 2003).

- Acyclic sports - jumps (long jump, high jump, triple jump, pole jump), motoring, badminton, hockey, *judo*, Greco-Roman and free wrestling, motorcycling, fencing, tennis (Tache & Galea, 2003).

Bompa (2002) mentions the same thing but focusing on judo, namely that in this sport, the following aerobic and anaerobic energy systems should be developed during a long training period:

- the dominant energy systems: the types of anaerobic alactacid exercise and aerobic lactacid exercise;
- the limiting factors: start power, power-resistance (P-R), reactive power, muscle resistance (M-R);
- the objectives of training: start power, reactive power, power-resistance (P-R), muscle resistance (M-R)

It can be seen that the objectives of training, according to Bompa (2002), are precisely the training or development of the limiting factors of exercise.

Due to the fact that according to the rules, judo competitions take place by age and weight categories (Table III), the indicators related to the height-weight ratio, i.e. the body mass index (BMI) and body composition, are extremely important. Determining weight and BMI allows to assign a subject to a certain weight category. However, based on this measurement, no information about the amount of adipose tissue is obtained. BMI can be increased in the absence of excessive fat tissue in relation to the age and height of the subject.

In athletes, the values of indicators should be interpreted based on the requirements of the different sports. Thus, in strength sports, the indicators will be much higher compared to sports games or other sports. In judo, like in other sports related to weight categories, forced weight loss in juniors is forbidden (until the end of growth and development processes); they will periodically change the weight category, because forced weight loss by only 2% of the body weight reduces muscle efficiency by 20%. Optimal weight will be regulated based on the nutritional state (Cordun, 2009).

In athletes, the body composition differs depending on the constitutional biotype (characteristic of different sports or sport branches), the training condition, the training period, and diet. The optimal mean values of fat tissue in men range between 6-13% (Cordun, 2009; Toacă, 2002). When the excess of fat tissue coexists with a normal active mass, sports performance is not af ected (Cordun, 2009).

Studies conducted on motor behavior in postpubertal/ adolescent judoka (U 18, U 16 and U15), as mentioned before, are relatively few in the Romanian literature, so that their contribution to obtaining superior performances in judo is insignif cant (Table III).

Table III

Age and weight categories (***, 2019).

Category	Year of birth	Male (kg)	Fight duration	Golden Score
Juniors CADETS U 18	2002, 2003, 2004	Indiv:46,50,55, 60,66,73,81, 90,+90 Teams:60,66,73, 81,+81	4'	No time limit
Juniors III- U 16	2004-2005	Indiv: 38, 42, 46, 50,55, 60, 66, 73, 81,+81	3 min.	No time limit
Juniors IV- U 15	2005-2006	Indiv:34, 38, 42, 46,50,55, 60, 66, 73,+73	3 min.	Max. GS 2 min

Judo competitions take place by age and weight categories. For each age category, there are at least 8 weight categories. Nevertheless, very many athletes reduce their body weight in several days, before competition, in order to obtain a competitive advantage over their lighter opponents. To obtain a rapid weight loss, athletes use a number of aggressive nutritive strategies, so that many of them place themselves at a high health risk. Rapid weight loss has proven to af ect health negatively. In short, it can lead to acute cardiovascular dysfunction, a decrease in bone density, af ecting thermoregulation, cognitive function, it can induce hormonal imbalance, growth def ciency, etc. In 1997, three judoka died as a result of using such rapid weight loss diets. Following these deaths, the International Judo Federation implemented a weight management program, which was ef ective in improving this harmful behavior (Artioli, 2010).

Conclusions

1. Motor behavior in judo represents all the technical procedures acquired by an athlete, converted to highly ef ective motor skills, with the aim of being used in competitions, with superior coordination, speed, strength, balance, mobility, f exibility indicators.

2. Behavior is continuously improved through continuous regulation and self-regulation of the technique and manifestation of the level of abilities/motor skills specif c to judo, by continuously changing/increasing the stimuli/exercises used during training. An important role is played by the coach.

3. Identifying the mechanisms to stimulate the capacity of adaptation, regulation and ef ective f ne self-regulation of specif c movements, determining its level and implementing training strategies to improve it are factors that favor or limit sports performance in judo.

4. The need for the acquisition of technical procedures with the highest accuracy allows for the training of an ef ective wrestling style, based on the biopsychomotor particularities of the judoka.

5. Applying the acquired motor skills, under conditions of routine training and subsequently competitive stress, to which the body has to adapt through specif c adaptability methods, is a condition of sports success; the continuous scientif c increase of exercise parameters: volume, intensity, complexity, density.

Conf icts of interests

No conf icts of interests.

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Obesity and physical activity

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Abstract
Obesity is an important health problem all over the world, leading to increased morbidity and mortality. Obesity related cardiometabolic complications are particularly associated with visceral fat deposition which induces systemic inf ammation, insulin resistance and diabetes mellitus. Visceral adiposity increases the risk of hypertension, coronary artery disease and stroke. In athletes, increased body mass index does not ref ect precisely fat body content because of increased muscular mass. Therefore, methods that estimate body composition are recommended to estimate nutritional status. Usually, a rigorous body weight control in athletes is required. Abnormally high body fat composition in athletes can lead to pathological complications.
Keywords: obesity, visceral fat, physical activity, body fat content.

Introduction

Overweight and obesity are two conditions characterized by an increase in fat mass accumulation. The prevalence of obesity is increasing across the world, with approximately 50% of adults expected to be obese by 2030 (***, 2014). Obesity is the result of a positive energy balance which is inf uenced by environmental and genetic factors. Excess obesity morbidity and mortality are related to many important obesity associated comorbidities, including hypertension, atherosclerosis with its coronary and cerebral complications, type 2 diabetes, obstructive sleep apnea, gastroesophageal ref ux disease, fatty liver disease, cholelithiasis, osteoarthritis, polycystic ovary syndrome and various types of cancer (gallbladder, esophagus, kidney, uterus, colon and breast) (***, 2002). Physical exercise is an essential means to prevent and to reduce body weight.

Obesity in athletes requires a complex evaluation because the increase in muscle mass can modify classical parameters such as the body mass index (BMI). The aim of the narrative review is to emphasize the cardiometabolic complications of obesity, the therapeutic role of physical exercise, and to present some particularities of nutritional status in athletes.

Obesity and cardiometabolic related complications

BMI is the most widely used parameter to estimate clinical obesity and overweight, and is calculated as the ratio between body weight and squared height. According to the values of BMI, nutrition status is classif ed as obesity for BMI=30-39.9 kg/m², extreme or morbid obesity for values equal or superior to 40 kg/m². Normal weight is def ned as a BMI of 18.5-24.9, while overweight is classif ed as BMI values of 25-29.9 kg/m² (Lopez et al., 2006). BMI is considered a surrogate marker for total body fat. It has been shown that obesity complications are related not only to the body fat content, but also to adipose tissue distribution. Central obesity, which ref ects visceral fat deposits, is a more important risk factor for cardiovascular diseases than subcutaneous fat. Central obesity can be estimated by the waist circumference and waist to hip ratio (WHR). The cut points for waist circumference ≥94 cm in men and ≥80 cm in women indicate abdominal obesity, as stated by the World Health Organization/International Diabetes Foundation (Millen et al., 2014). When BMI was used as a measure of obesity, the association with cardiovascular morbidity was modest (Guarner & Rubio-Ruiz, 2015). In contrast, when using waist circumference or waist to hip ratio as a measure of abdominal adiposity, the association with cardiovascular and metabolic syndrome was strong (Czernichow et al., 2011; Vakil et al., 2012).

Visceral fat or ectopic fat may surround the heart and arteries or inf ltrate organs such as the liver, muscles and kidneys. Fat surrounding the heart is located between the internal border of the mediastinum and the external surface of the parietal pericardium (pericardial fat), or within the

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pericardial sac (epicardial fat) or the visceral epicardium, surrounding the coronary arteries (pericoronary fat). This ectopic fat tissue produces inflammatory cytokines which induce vessel wall inflammation and may stimulate the development of atherosclerosis (Yudkin et al., 2005). This fat content may be measured using echocardiography and more precisely using multidetector computed tomography or magnetic resonance imaging which quantifies adipose tissue volume (van der Kooy & Seidell, 1993; Lim, 2014).

Perivascular fat is a source of cytokines that stimulate inflammation inducing endothelial dysfunction and atherosclerosis (Yudkin et al., 2005). Perivascular fat can be measured using computed tomography examination and magnetic resonance imaging methods (Lim, 2014).

In an animal model, increased renal sinus fat was associated with increased blood pressure, probably by compression of blood vessels (Chughtai et al., 2010), while intrarenal fat was associated with inflammation, oxidative stress and renal fibrosis (Reisin & Jack, 2009). Renal sinus fat can be measured by computed tomography scan. Perirenal fat can be explored ultrasonographically (Lim, 2014).

Ectopic fat accumulation in the liver stimulates the production of inflammatory cytokines, increases insulin resistance and stimulates VLDL hepatic synthesis (Lo et al., 2011). Diagnosis of fatty liver disease can be made using ultrasonography, computed tomography or H-magnetic resonance spectroscopy (Lim, 2014).

Muscle fat infiltration is considered an important cause of insulin resistance. The alteration of fatty acid oxidation leads to diminished use of fatty acids and increased lipid storage within skeletal muscle. Fat muscle deposition can be measured using dual-energy X-ray absorptiometry or computed tomography scan (Lim, 2014).

In visceral adiposity, adipocytes are hypertrophied and dysfunctional. Abdominal obesity has been linked to insulin resistance and systemic inflammation which contribute to the development of type 2 diabetes mellitus, hyperlipidemia and cardiovascular disease (Marsland et al., 2010).

The association of obesity with impaired glucose tolerance and with diabetes mellitus has been shown in large studies in both women and men (Frank et al., 2001; Chan et al., 1994). The precise mechanism that contributes to this association is not known, but increased insulin resistance in obesity seems to play an essential role (Paley & Johnson, 2018). Adipokines secreted by adipose tissue have an important role in obesity related cardiometabolic complications. Adiponectin, which increases insulin sensitivity and protects the cardiovascular system, is reduced in obesity. Leptin regulates food intake and energy expenditure and is also involved in muscle fatty acid metabolism and hepatic glucose synthesis. Obesity is characterized by increased leptin levels and leptin resistance. Interleukin 6 and tumor necrosis factor-α are inflammatory cytokines involved in the relation between systemic inflammation, insulin resistance and obesity (Lechleitner, 2008).

Obesity is also strongly related to arterial hypertension. The relative risk of hypertension in overweight men and women was 1.46 and 1.75, respectively, after adjusting for age, in the Framingham study (Wilson et al., 2002).

Insulin resistance is an essential mechanism in the development of metabolic syndrome. The inadequately high energy intake causes overloading of adipose tissue, and lipids that cannot be stored in adipocytes accumulate in ectopic sites, such as the liver, skeletal muscle and pancreas, inducing organ functional impairment. Obesity is associated with reduced high-density lipoprotein and increased triglycerides. Insulin resistance impairs lipoprotein lipase, inducing alteration of lipid metabolism (Reisin & Jack, 2009).

Coronary heart disease has been reported to be more frequent in obese subjects (Willett et al., 1995). Chronic heart failure was 2 times more frequent among obese compared to non-obese patients (Kenchaiah et al., 2002). However, several studies have found better outcomes in overweight and obese patients with coronary heart disease and chronic heart failure compared to normal weight subjects. This phenomenon has been described as "an obesity paradox" (Segula, 2014; Hainer & Aldhoon-Hainerova, 2013). The obesity paradox mechanism is not completely understood, but it is supposed that these patients are elderly, and their obesity is not accompanied by the metabolic changes that characterize abdominal obesity (Hainer & Aldhoon-Hainerova, 2013).

An increased risk of ischemic stroke has been associated with obesity. Moreover, in central obesity, trunk adipose tissue distribution was associated with stroke mortality (Segula, 2014; Tanne et al., 2005).

In contrast, there are also obese subjects who are metabolically healthy (about a quarter of the obese adult population), with insulin-sensitive obesity, and do not develop systemic inflammation. On the other hand, unhealthy lean subjects develop metabolic and vascular complications even though they have a normal BMI. In these cases, ectopic visceral adipose tissue, particularly perivascular and pericardial fat, might be the cause of altered metabolic status (Denis & Hamilton, 2013).

Effects of exercise on body weight and metabolic alterations in obesity

Obesity and metabolic syndrome have been associated with sedentary behavior (Telford, 2007; Lakka et al., 2003). The risk for developing metabolic syndrome was 65% in men with a moderate level and 76% in those with a high level of sedentary behavior, compared to men who were active (Greer et al., 2015). Active people and athletes are less obese than sedentary people.

The combination of exercise and diet offers a method for weight control. Research indicates that exercise may increase lipid mobilization from the adipose tissue and fat utilization, thus increasing fat weight loss and, at the same time, preventing the reduction of lean tissue (Kenney et al., 2015). There are three essential ways that contribute to weight loss: reducing caloric intake below daily energy expenditure, maintaining regular food intake, and increasing energy expenditure by performing additional physical activity, and using combined methods which induce a negative energy balance by decreasing food intake and increasing energy expenditure (Westerterp, 2010).

Physical exercise has been shown to improve various markers of metabolic syndrome. In a large longitudinal study which included 4840 adults, overweight and obese individuals who increased the physical activity level improved their BMI and cardiometabolic profile with a decrease of LDL cholesterol from baseline to follow-up (536 days) (Ritti-Dias et al., 2017). In another prospective study which included 22,383 participants aged 30-64 years, without metabolic syndrome, who were followed up for a mean of 4.1 years, leisure-time activity was found to be linearly and inversely correlated with the risk of developing metabolic intensity activity associated with a lower risk of metabolic syndrome (Kuwahara et al., 2016). Studies that investigated the effects of physical training on various components of metabolic syndrome found an improved risk profile with exercise (Ostman et al., 2017; Lin et al., 2014).

The effects of exercise on abdominal obesity even in the absence of weight loss have also been studied. It has been reported that moderate intensity exercise significantly reduces total and abdominal fat, skeletal muscle lipid content, even in the absence of weight loss (Paley & Johnson, 2018; Lee et al., 2005).

At least 200 to 300 minutes of moderate to vigorous physical activity each week have been recommended to encourage long-term weight loss (Lee et al, 2013; Goldberg et al., 2009). In order to prevent weight regain and increase weight loss, 150 to 300 minutes of moderate physical activity per week or 75 to 150 minutes of vigorous physical activity weekly are recommended (Lee et al., 2013).

The mechanisms involved in the effects of exercise on obesity are not completely understood. The main theories emphasize the decline in inflammatory cytokine levels (such as interleukin-1, tumor necrosis factor-*α* and monocyte chemoattractant protein 1), oxidative stress, and the increase in adiponectin, as favorable effects of exercise training (Sakurai et al, 2013; Werner et al, 2013).

Body weight and fat content in athletes

Body weight in athletes depends on the type of sport. Certain sports impose a rigorous control of weight. Aesthetic sports such as rhythmic and artistic gymnastics, ice skating, or endurance sports such as long-distance running are sports which require low body weight for high quality sport activity (Ritti-Dias et al., 2017). In other sports, including wrestlers, boxers, judokas, mixed martial artists, power lifters, and weightlifters, weight classes are defined for sports competitions. Athletes usually improve muscle strength without augmenting their BMI because participating in a superior body weight class may be more difficult (Dragan, 2002; ***, 2017).

BMI is a surrogate marker of body fat and is less precise in the estimation of athletes' nutritional status, as they may have a higher BMI due to higher lean mass. Body fat content estimated as the ratio of body fat mass to body free-fat mass is essential for elite athletes because it may influence athletic performance. Thus, in athletes, methods that estimate body composition are recommended (***, 2017; Popadić Gaćeša et al., 2011).

It has been found that a body fat percentage of 7% to 9% is metabolically efficient and healthy for most males, while for females, the adequate body fat percentage is 12% to 15% (Perriello, 2001).

One example of increased BMI which does not reflect exactly the amount of fat is that of sumo wrestlers. Sumo is the national sport of Japan and has a 2000-year history. Sumo athletes have an intensive exercise regimen and consume a very high calorie diet daily (more than 5,000 cal). The frequency of meal intake is twice daily (Yamauchi et al., 2004). In one study that evaluated the BMI and fat content in sumo wrestlers compared to controls, all wrestlers were obese according to their BMI but only 40% were so when their body fat was taken into consideration. This suggests that both the BMI and fat percentage can be considered when assessing obesity in excessively muscular people.

An abnormally high body fat composition in athletes can lead to pathological complications including high blood pressure, hyperlipidemia, heart disease, diabetes, and gallbladder disease (Perriello, 2001).

In a study that included 96 wrestlers with a mean body weight of 100.4 kg, the mean serum levels of triglycerides, phospholipids, uric acid, and total protein were significantly higher in wrestlers than in age-matched healthy males. The incidence of diabetes mellitus, gout, and hypertension was considerably higher in athletes than in controls. A high calorie diet and infrequent meal intake were considered as possible causes of obesity, hyperlipidemia, and hyperuricemia in wrestlers (Nishizawa et al., 1976).

Conclusions

1. Obesity, particularly its visceral type, is associated with an increased risk of cardiometabolic diseases. Physical exercise can reduce body weight and the risk of obesity complications.
2. In athletes, obesity must be estimated not only by the measurement of BMI, but also by the body fat content.
3. The increase of fat mass reduces athletes' performance and increases the risk of cardiac and metabolic diseases.

Conflicts of interests
The authors have no conflicts of interests.

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A current challenge of rehabilitation medicine: the management of disabilities induced by acute SARS-CoV-2 infection

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Abstract
Coronavirus 2 (SARS-CoV-2) was a new type of coronavirus that appeared in 2019 and caused a disease with a predominantly severe manifestation of the respiratory tract (COVID-19). Patients who have survived this condition could develop as a complication a syndrome characterized by physical, mental and cognitive disorders. "Intensive care post-syndrome" may also develop which, in addition to the respiratory system may require complex musculoskeletal rehabilitation. SARS-CoV-2 infection can af ect various organs and systems (respiratory, neurological, cardiac, ocular, gastrointestinal and others), with a strong impact on the functionality of af ected patients; in the long term this could cause various disabilities.

The extent of the problem in terms of severity and incidence of dysfunction and disability is still unknown, but early research suggests that the patients concerned will need rehabilitation at all stages of the disease - acute, post-acute and long-term, presenting concomitant respiratory neurological, musculoskeletal, psychiatric conditions.

Current research suggests that the integrated medical rehabilitation service with the care of patients with SARS CoV-2 of ers benef ts for both the patient and the medical system in general. Studies on post-COVID-19 medical rehabilitation services are preliminary, the pandemic generated by COVID-19 being a complex situation, little known by health systems. At the same time, numerous clinical trials of er recommendations on interventions and principles for organizing rehabilitation care for this category of patients.

Keywords: SARS-CoV-2 infection, respiratory rehabilitation, musculoskeletal rehabilitation, organization of post-COVID rehabilitation services.

Introduction

Coronavirus 2 (SARS-CoV-2) was a new type of coronavirus that appeared in 2019 and caused a disease with a predominantly severe manifestation of the respiratory tract (COVID-19). Patients who have survived this condition could develop as a complication a syndrome characterized by physical, mental and cognitive disorders. "Intensive care post-syndrome" may also develop, which in addition to the respiratory system may require complex musculoskeletal rehabilitation (Guan et al., 2020).

COVID-19 most often manifests as a f u-like respiratory infection with fever (89%), cough (68%), fatigue (38%), respiratory secretion (34%) and/or breathing dif culty (19%). Symptoms can range from an asymptomatic infection to a mild upper respiratory illness, to severe viral pneumonia, but respiratory failure can also develop which can eventually be fatal. Current data suggest that 80% of cases are asymptomatic or mild; 15% of cases are severe (the disease requires oxygen administration) and 5% are critical, requiring mechanical ventilation and interventions that support vital functions (***, 2020; Guan et al., 2020); (1); (2).

SARS-CoV-2 infection can af ect various organs and systems (respiratory, neurological, cardiac, ocular, gastrointestinal, etc.), having a strong impact on the functionality of af ected patients, and in the long term it can cause various disabilities (***, 2020; Guan et al., 2020); (1); (2).

Recent research suggests that the integrated medical rehabilitation service with the care of patients with SARS-CoV-2 of ers benef ts for both the patient and the medical system in general. Studies on post-COVID-19 medical rehabilitation services are preliminary, the pandemic

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generated by COVID-19 being a complex situation, little known by health systems. At the same time, numerous clinical trials of er recommendations on interventions and principles for organizing rehabilitation care for this category of patients (Wade, 2020).

Complications associated with SARS-CoV-2 infection

Multiple complications occur after COVID-19 infection, with a frequency that is still being studied. Although known to have tropism on the respiratory system, the virus can af ect the heart and cardiovascular system, the brain directly (encephalitis) and indirectly (secondary to hypoxia or vascular thrombosis), the renal function with altered blood clotting mechanisms, the gastrointestinal tract or liver function. There is also a psychosocial impairment which has a signif cant importance: at the time of diagnosis, patients become anxious and due to isolation there are social problems (feeling abandoned) (Wade, 2020).

The extent of the problem in terms of severity and incidence of dysfunction and disability is still unknown, but early research suggests that these patients will need rehabilitation at all stages of the disease - acute, post-acute and in the long term (Wade, 2020). Recent research suggests that over 50% of patients with COVID 19 who required hospitalization show marked fatigue 60 days after the onset of symptoms. A current study shows that 3 months after the onset of the disease, one third of the patients who were not hospitalized had the same degree of dependence on their relatives/caregivers as in the acute phase of the disease. It has also been shown that regardless of the severity of the disease, patients may experience persistent symptoms and a progressive functional decline that is not evident at a routine consultation, such as cognitive impairment that did not exist prior to SARS-CoV-2 infection. Manifestations with late onset may continue to occur in the rehabilitation phase of the disease; distant ef ects of COVID-19 disease have been reported consisting of inf ammatory, thromboembolic or autonomic complications - stroke, pulmonary thromboembolism and acute myocardial infarction (Stam et al., 2020); (3).

Rehabilitation can be a key strategy to reduce the impact of COVID-19 on health and functionality. The consequences of COVID-19 will be specif c to each individual, and their rehabilitation needs will be individualized according to these complications (Wade, 2020).

The existence of specif c syndromes that appear after COVID-19 infection and are due to prolonged hospitalization in the intensive care unit has already emerged. Changes that occur after prolonged hospitalizations in intensive care can be summarized as follows:

- *Critical Illness Polyneuropathy*, characterized by - dependence on mechanical ventilation, generalized and symmetrical weakness (includes diaphragmatic weakness), distal sensory disorder, atrophy, possibly associated with pain, sphincter incontinence, decreased joint amplitude of movement, dysphagia, anxiety, depression.

- *Critical Illness Myopathy* is a non-necrotic myopathy, dif use, with fatty degeneration, atrophy and f brosis of muscle f bres.

- *Post-Intensive Care Syndrome*, characterized by cognitive impairments - memory, attention, psychomotor disorder, anxiety, depression, dyspnoea with impaired lung function by reducing inspiratory muscle strength, pain, sexual dysfunction; low tolerance to exercise, neuropathy, muscle weakness/paresis, severe fatigue, reduced functional capacity (Stam et al., 2020; Lazzeri et al., 2020); (3); (4);

The most important and common complications that occur in COVID-19 infection can be classif ed as follows:

- *heart damage*: arrhythmias, heart failure, decreased ejection fraction, increased troponin I, severe myocarditis with reduced systolic dysfunction; the presence of cardiac lesions should always be considered in a patient after COVID-19 infection if suggestive symptoms occur;

- *musculoskeletal impairment*: physical deconditioning, severe muscle weakness, reduced joint mobility, pain in the neck and shoulders (due to prolonged position in a prone position), dif culty standing, lack of balance and gait (Lazzeri et al., 2020; Vitacca et al., 2020);

- *pulmonary damage*: pulmonary f brosis; abundant bronchial secretions (Lazzeri et al., 2020; Vitacca et al., 2020);

- *neurological impairment*: headache, impaired consciousness, epileptic seizures, anosmia, ageusia, paresthesias, encephalopathies, encephalitis, stroke, Guillain Barre syndrome, swallowing disorders;

- *psychiatric impairment*: cognitive impairment, delirium, confusion.

- *other disorders*: voice disorders - diphonia, xerostomia, knot in the throat, vocal fatigue, burning sensation in the pharyngo-larynx (4); (Stam et al., 2020; Lazzeri et al., 2020).

General principles and organization of the post-COVID-19 medical rehabilitation service

Organizing a multidisciplinary medical team is essential to ensure the most complex recovery of patients, as COVID-19 is a multisystemic disease. The rehabilitation team must have skills in the diagnosis, management and prognosis of complex disabilities associated with SARS-VOC-2 infection, and must take into account international guidelines for the rehabilitation of various conditions that SARS-VOC-2 infection has caused (thrombotic events with their consequences - stroke, acute myocardial infarction, acute ischemia of the limbs, phenomena of direct invasion - meningitis, myocarditis, myositis; or immune-mediated reactions - for example Guillain-Barre syndrome) (Stam et al., 2020; Righetti et al., 2020); (3).

The decision regarding the optimal time to start the post-COVID-19 medical rehabilitation program belongs to the multidisciplinary team that will coordinate the rehabilitation program and must be according to patient's health. The working conditions and logistics dedicated to the rehabilitation process must also be individualized on a case-by-case basis, so that even patients who still remain contagious can benef t from such a recovery program (4); (Stam et al., 2020); (3).

The rehabilitation program must be customized according to the patient's needs, functional def cits and comorbidities. Rehabilitation of patients after COVID-19 will focus on improving the symptoms of dyspnoea, psychological stress, limiting physical capacity, with the gradual increase in the intensity of the rehabilitation program, the ultimate goal being to improve physical condition and quality of life. The initial assessment and functional re-assessment must be performed throughout the rehabilitation period. Patients should receive information about their health and must be educated on self-management strategies, symptom control and rehabilitation interventions (Lazzeri et al., 2020); (6).

In the case of patients who have been hospitalized, rehabilitation after discharge must be a continuity of interventions during the acute period, and is a condition for ensuring the safety of the act of discharge from the hospital. Upon discharge, the patient's medical condition corroborated with SARS-COV-2 secondary disabilities should be evaluated and a rehabilitation plan designed to take into account all these medical data, including the need for oxygen therapy at home, the need for assistive devices, and also the possibility of adapting the environment to which the patient returns to his new dysfunctions should be implemented. In post-COVID-19 recovery, there may be a frequent decrease in the oxygen saturation of the arterial blood when exercising or during light/moderate exertion, without correlation with SaO2 at rest or with the subjective sensation of dyspnoea; this situation can be predicted by applying a 1-minute sit-to-stand test (Stam et al., 2020); (3).

After discharge from the hospital, rehabilitation specialists will develop the rehabilitation program with a gradual increase of physical ef ort, will educate patients on how to conserve energy and on changing behaviour, will provide solutions to adapt the environment at home and at work, will recommend the use of assistive walking devices, as well as rehabilitation interventions for any individual functional def ciencies. Patients will be trained to save energy and avoid physical exhaustion, adapting daily activities to individual physical tolerance and symptoms; exercise will also be adapted according to the severity of symptoms (Stam et al., 2020; (3); (6).

The need for rehabilitation must be met through long-term rehabilitation services accessed by patients in a timely manner. In case of dif cult access to such medical services, patients and their relatives should be guided to information sources (printed materials, video recordings, etc.) to ensure the acquisition of self-management techniques of post-COVID-19 symptoms. In the case of transfer from a COVID hospital to a recovery centre, it is essential to share patient's medical data between the two medical teams, in order to ensure the qualitative continuity of the medical act (Stam et al., 2020); (3); (4).

In specialized rehabilitation centres, patients with complex needs must have access to medical methods, facilities and equipment, and the medical and paramedical staf trained in rehabilitation care must follow preventive measures, use appropriate personal protective equipment in accordance with local standards, policies and international measures (Righetti et al., 2020).

At present, there is no consensus on strict limits regarding the chronological staging of medical rehabilitation for people who have contracted SARS CoV-2 infection. Rehabilitation interventions can be conventionally divided into acute phase (the patient is hospitalized in the intensive care unit), subacute (stabilization of the patient's vital functions after the critical condition) and long-term (after discharge from the hospital) (Wade, 2020).

During long-term recovery after severe COVID-19, patients can benef t from pulmonary rehabilitation interventions which aim to alleviate respiratory and physical def ciencies by indicating physical activity programs, education, involvement in daily activities and psychoeducation interventions, screening depression and suicidal ideation, psycho-emotional support (Wade, 2020; Keyse, 2015).

Post COVID-19 rehabilitation can be performed at all levels: hospital, outpatient and home, including the use of telemedicine (Lazzeri et al., 2020; Righetti et al., 2020); (4); (6).

Objectives of post-COVID-19 medical rehabilitation

The rehabilitation team of the service dedicated to patients who went through SARS-CoV-2 infection must focus on establishing the clinical-functional diagnosis, correlating clinical, biological, imaging data with discussions with the patient and his family to determine the real functional needs (Stam et al., 2020; Wade, 2020).

The objectives of short-term rehabilitation are to improve joint mobility, to increase endurance and muscle strength, to improve breathing, adaptation to ef ort, to re-educate ADLs.

The objectives of long-term rehabilitation are to obtain functional independence, return to social, professional and recreational activities.

In order to achieve these targets, it is essential to select rehabilitation interventions and to develop individualized programs, to estimate risks, complications, and functional and psychosocial limitations (Stam et. al., 2020; Lazzeri et al., 2020).

Functional impairments and post COVID-19 sequelae

COVID-19 infection can cause respiratory def ciencies of varying degrees of severity, as well as many other manifestations and extrapulmonary functional def ciencies. The rehabilitation plan must be individualized and patient-centered.

Rehabilitation objectives are established in relation to the functional impact of COVID-19 infection on the respiratory system and other systems/organs taking into account personal, environmental and pre-existing comorbidities.

The most common sequelae and dysfunctions after SARS-CoV-2 infection are as follows:

- *respiratory sequelae*: dyspnoea, pulmonary f brosis, expectoration def ciencies, pathological breathing patterns, hyperventilation (Lazzeri et al., 2020; Vitacca et al., 2020);
- *musculoskeletal sequelae*: physical deconditioning and fatigue, severe muscle weakness, joint hypomobility,

myalgia, balance and gait disorders, decreased exercise tolerance;

- *neurological sequelae*: headache, disturbances of consciousness, convulsive syndrome, altered sense of taste and smell, paraesthesia, reversible encephalopathy syndrome, viral encephalitis, increased risk of stroke, polyneuropathy;
- *cardiac sequelae*: arrhythmias, heart failure, reduced ejection fraction, myocarditis
- thromboembolism, coagulopathies;
- *psychiatric sequelae*: distortion of body image, loss of dignity and control, anxiety, panic attacks, emotional lability, depression, self-pity, confusion, post-traumatic stress, suicidal ideation;
- *other types of sequelae*: limitation of daily activities (ADL), dysphagia, speech disorders, dysphonia with vocal fatigue, decreased tone of voice, xerostomia, impaired swallowing, gastrointestinal disorders, visual disturbances (Stam et. al., 2020; Lazzeri et al., 2020); (4).

Initial functional evaluation and evaluation of the results of the rehabilitation program

Functional evaluation of the patient who has undergone COVID-19 infection is performed during the specialized clinical rehabilitation medical examination. It is recommended to use accessible, easily applicable tests without overburdening the patient and without additional costs. The multidisciplinary team must use the same means of evaluation for ef ective communication and for monitoring functional progress. The following functional tests may be applied to assess cardiorespiratory function and overall exercise tolerance:

- Patient Specif c Functional Scale - assessment of the perception of limits in performing daily activities.
- International Physical Activity Questionnaire - assessment of functionality and disability.
- Monitoring oxygen saturation and vital signs (HR, BP, RF) before, during and at the end of the rehabilitation session.
- Borg scale and Borg CR10 - assessment of the degree of dyspnoea and fatigue.
- Berg scale - balance assessment.
- Medical Research Council dyspnoea scale.
- 6-minute walking test - functional capacity.
- Dysphagia severity scale.
- Barthel score - assessment of daily functional abilities (ADL).
- Mini Mental State Examination Scale.
- Visual analogue scale of pain.
- 30-second sit-up test - limited functional capacity.
- Goniometry - assessment of joint balance.
- Manual muscle testing - evaluation of muscle strength.
- Other tests and examinations as needed (3); (4); (Lazzeri et al., 2020; Keyse et al., 2015).

Rehabilitation of pulmonary sequelae after COVID-19

Pulmonary rehabilitation includes physical therapy programs and interventions aimed at increasing strain tolerance. Rehabilitation programs for post COVID-19 patients should be developed in conjunction with respiratory complications and other conditions/sequelae that impose general functioning restrictions (Vitacca et al., 2020; Sbenghe, 2020).

The initial assessment is recommended in a timely and safe manner depending on the degree of normocapnic respiratory failure, as well as on coexisting conditions. Low-intensity exercise (≤3 METs or equivalent) should be considered especially for patients in need of oxygen therapy with simultaneous monitoring of vital parameters (HR, RF, BP, pulse oximetry). Exercise intensity should be gradually increased in relation to the evolution of symptoms and the general condition of the patient (Vitacca et al., 2020; Simonelli et al., 2020).

The objectives of post-acute rehabilitation of SARS-CoV-2 infection are: reduction of dyspnoea, respiratory re-education, facilitation of expiration, maintenance/ increase of joint mobility, increase of muscular strength, cardiorespiratory adaptation to physical ef ort, rehabilitation of speech and swallowing, improvement of the behavioural component (hygiene and diet plan, avoidance of sedentary lifestyle, avoidance of toxic consumption), ADL training, social reintegration (5); (Vitacca et al., 2020; Sbenghe, 1987; Winck & Ambrosino, 2020).

The means to achieve these goals are: early mobilization, re-education of transfers, training of respiratory muscles, re-education of diaphragmatic breathing, facilitation of expectoration, learning breathing and expectoration facilitation positions, re-education of cough, positive expiratory pressure therapy (PEP), stimulating spirometry, static and dynamic breathing exercises, joint mobilization, endurance exercises, aerobic training, tolerance training to exercise, phonation and swallowing re-education techniques, electrical stimulation of hypotrophic muscles, oxygen therapy, occupational therapy, psychological counselling, psychological intervention of short duration and psychotherapy, psychosocial support of the patient and/or caregivers (family members) and balneotherapy (5); (Keyse et al., 2015; Sbenghe, 1987; Matcovschi et al., 2011).

The basic components of pulmonary rehabilitation are: *kinesiotherapy*, *electrotherapy*, *balneotherapy*

a) Kinesiotherapy consists of: aerobic exercises - walking, brisk walking, jogging, swimming, etc., starting from low intensity with gradual increase of intensity and duration of ef ort, repeated 3-5 times a week, 20-30 min for each session; strength training - progressive resistance training is recommended, the training load for each target muscle group is 8-12 repetitions, 1-3 muscle groups/ time unit, the training interval of each group is 2 minutes, 2-3 times/week with increasing training load by 5% -10% per week; re-education of coordination and balance - patients with balance and coordination disorders require involvement in activities aimed at restoring balance, including the use of assistive devices (crutches, sticks, walking frame); respiratory re-education (Righetti et al., 2020; Sbenghe, 1987; Matcovschi et al., 2011).

If after discharge from the hospital patients have symptoms such as dyspnoea, changes in the respiratory pattern, productive cough, respiratory rehabilitation is recommended. This includes postures, postural drainage, percussion and vibration manoeuvres of the chest (chest physiotherapy), adjustment of respiratory rate, breathing exercises with training of the respiratory muscles and training on cough and correct expectoration (Lazzeri et al., 2020; Abdullahi, 2020; Bhutani et al., 2020). Active segmental mobilization should be followed by progressive muscle toning in individual rehabilitation programs. Aerobic reconditioning can be done by walking, bicycle riding. Progressive aerobic exercise can be subsequently increased to 20-30 minutes daily. The physical therapy program will be specif cally adapted for the disability that occurs as a result of SARS-CoV-2 infection; it is not limited to respiratory physiotherapy but will also include the rehabilitation of other conditions and disabilities (e.g. neuromuscular, cardiac, psychiatric) (Sbenghe, 1987; Matcovschi et al., 2011; Keyse et al., 2015).

b) Electrotherapy includes procedures such as super inductive system therapy and laser therapy. Super inductive system therapy (SIS) aims to myostimulate weak muscles - diaphragm, intercostal muscles, to improve blood circulation and breathing. The procedure is applied daily, and 10 treatment sessions are recommended. It begins with the protocol for improving circulation on the dorsal side of the trunk (the area between the ribs 1-6), treating both sides (anterior application is not possible due to the heart). Application is continuous with improved breathing, stimulating the diaphragm (on both sides: left-right) and intercostal muscles (lateral and posterior parts; the anterior part can be ef ectively treated only on the right side of the body). The intensity is adjusted individually with the control of the motor response; it increases gradually ensuring maximum patient comfort throughout the treatment (Miranda et al., 2015).

LASER therapy aims to improve respiratory symptoms and subjective complaints of patients: improvement of cough, dyspnoea, tachypnoea, fatigue, and increased exercise capacity, objective improvement of lung function: decrease in the need for O2 intake, increased environmental oxygen saturation in arterial blood, improvement of COVID-19 pneumonia severity scores (SMART-COP and BresciaCOVID), improvement of disease progression from a biochemical (reduction of inf ammatory, immunological markers) and imaging point of view (decrease in lung damage on two-dimensional radiography and chest CT scan), improving the independence and performance of ADLs, shortening the recovery period after COVID-19 induced pneumonia, being an adjunct to classical methods of pulmonary rehabilitation (physiotherapy) (Sigman et al., 2020a; Sigman et al., 2020b; Mokmeli et al., 2020; Mehani, 2017).

The biological and clinical ef ects of laser therapy consist of the production of photochemical cellular reactions that activate the biomolecules responsible for restoring normal cell function, increasing the healing speed of lung parenchymal tissue through tissue regeneration in acute lung lesions, decreasing the number of proinf ammatory cytokines by modulating the "cytokine storm" and the acute respiratory distress syndrome, reducing lung inf ammation at molecular, cellular and tissue level, reducing pulmonary oedema, relieving lung pain, increasing lung volume and exercise capacity (Nejatifard et al., 2021; de Brito et al., 2020; Fekrazad, 2020; Cury et al., 2016; de Lima et al., 2011).

The advantages of laser therapy are the following: the procedure is non-invasive, painless, it involves low costs compared to benef ts, has no known side ef ects (reported) if the therapeutic parameters established in the studies are applied, and the epidemiological risk is low – non-contact application method (Fekrazad, 2020, quoted by da Cunha et al., 2018).

Method of application - use of low power laser emitting in the range of 905-808 nm, at a frequency of 1500 Hz, at a dose of 7.2 J/cm^2, 20 cm above the skin, with scanning of each lung f eld, from the apex to the lung bases, 1 session/day, for 4 consecutive days (Sigman et al., 2020a; Sigman et al., 2020b).

c) Balneotherapy can be indicated between the rehabilitation stages within the hospital, the patients following treatment courses in resorts dedicated to the treatment and recovery of respiratory diseases. It consists of aerotherapy, fumarole, saline therapy, aerosols and inhalations with sodium chloride waters or iodinated waters (if the patient does not have a lung disease with a spastic component at the time of examination).

This therapy can be performed in resorts such as Turda, Praid, Ocnele Mari, Mangalia, Techirghiol, Eforie Nord, Tg. Ocna, Amara, Ocna Șugatag, Slănic Moldova, Slănic Prahova, Govora, Praid, Buziaș, Tușnad (for external treatment); Calimănești, Olănești, Herculane, Sacelu, Govora, Buziaș (for internal treatment) (Munteanu, 2013; Munteanu & Cinteză, 2011).

Therapeutic massage applied to the chest combined with physical therapy and electrotherapy has positive ef ects on increasing chest compliance with relief of dyspnoea, sputum, joint and muscle pain and decreased chest muscle contractions and subjective sensation of stif chest. Preliminary research suggests that therapeutic chest massage in patients recovering from COVID-19 improves the remaining symptoms and increases quality of life (Wu et al., 2021).

Rehabilitation of extrapulmonary sequelae after COVID-19

The rehabilitation management of the patient after COVID-19 is determined by the severity of clinical manifestations and functional def ciencies caused by the possible damage to several organs and systems. Their long-term impact on post-COVID-19 individuals is unknown. Recent studies and research show that survivors of COVID-19 infection can develop various neurological, musculoskeletal, psychological, physical and cognitive disorders, most of them with multiple comorbidities (Stam et al., 2020).

All patients requiring rehabilitation after COVID-19 should receive a specialized functional assessment for neurological, musculoskeletal and cardiac symptoms, as well as psychological and cognitive screening to determine the causes of residual phenomena and to carry out appropriate rehabilitation interventions (Lazzeri et al., 2020).

Rehabilitation of patients who have been admitted to intensive care units and those with multiple comorbidities prior to COVID-19 disease requires a multidisciplinary therapeutic approach involving the multiprofessional rehabilitation team. Patients with post-intensive care syndrome or after intubation should follow a rehabilitation program focused on physical and cognitive impairments. For these patients, in addition to the classic physiotherapy and electrotherapy program, special treatment methods such as occupational therapy and speech therapy must be approached to ensure complexity and efficiency of long-term rehabilitation (Stam et al., 2020; Copotoiu, 2007; Vitacca et al., 2020).

Occupational therapy uses physical exercises from ordinary human activities - life, work, entertainment, and is oriented towards the functional and psychological level of the patient. The main objectives of occupational therapy in post-COVID recovery are to restore the ability to move in all its aspects (amplitude, strength, muscular endurance, ability and coordination), motor and psychomotor education or re-education, sensory re-education, family reintegration, re-adaptation and integration in social and professional fields, restoring gestures, retraining and adapting to the daily life of the patient, adapting to temporary or permanent disability secondary to the disease, achieving maximum possible independence, stimulating positive free thinking, independence in ADL, during transfers and gait. It is mainly addressed to patients who have been hospitalized in an intensive care unit and who have been sedated, mechanically ventilated and immobilized on the bed for a long time (Irsay et al., 2016; Scott, 2020).

In the post-COVID-19 recovery process it is important to adapt the environment to the patient's functional abilities under the guidance of an occupational therapist who evaluates the environment in which the patient lives and works after discharge from the hospital; useful adaptations to the patient's home may be the installation of handles in the bathroom, in the shower and on the stairwell, the adaptation of the toilet bowl, the use of orthoses to facilitate walking and the degree of independence, learning to use assistive devices (3); (Scott, 2020).

Speech therapy along with occupational therapy is indicated in patients with vocal impairment, speech and swallowing disorders secondary to prolonged intubation or in the context of neurological impairment during the disease. These patients are at risk for food aspiration and may have deficits in expression and communication. It is recommended to apply breathing re-education exercises, re-education of swallowing solids and liquids, vocal exercises, pronunciation correction, correction of voice disorders, rhythm and fluency, learning gestural communication techniques, stimulating expressive communication (3); (Stam et al., 2020).

Rehabilitation of neurological and cognitive complications is extremely important and screening is required in all patients who have presented with COVID-19 for neurological manifestations as they may be immediate (at the time of active infection) or delayed (in the weeks following COVID-19). Cognitive evaluation of patients who have been hospitalized in ICU or have a residual cognitive impairment is also recommended. We need to make sure that mild neurological symptoms such as headache, dizziness, loss of smell and/or taste and other sensory disorders will go away soon. Physical, cognitive and functional assessments must be taken into account to support socio-professional reintegration (4); (Lazzeri et al., 2020). For patients with cognitive, memory, attention impairment, memory exercises, reading or various games such as puzzle are indicated. It is also recommended to learn strategies and methods to reduce stress and anxiety associated with cognitive impairment, for emotional support of these patients, and also to learn compensatory techniques - dividing complex activities into simple activities (3); Stam et al., 2020; Wade, 2020).

Rehabilitation of cardiac complications is done through specific individually adapted cardiac rehabilitation programs based on the evaluation of cardiac dysfunctions. Patients after ultrasound-confirmed myocarditis who return to performance sports require a period of 3-6 months of complete rest. The rest period depends on the clinical severity and duration of the disease, on the function of the left ventricle (4); (Lazzeri et al., 2020).

The rehabilitation of chronic post-COVID-19 pain is done by a multidisciplinary medical team, in order to ensure complex pain management according to the principle of the bio-psycho-social model (Stam et al., 2020).

In case of emergence of a new medical condition during the rehabilitation program, the patient should be referred to a specialist for its management (Lazzeri et al., 2020).

Situations that require the interruption/timing of the rehabilitation program

Safety is an extremely important element for the rehabilitation of patients with COVID-19. The occurrence of the following red flags requires the cessation/timing and individualized adaptation of the rehabilitation programs:

- Low SaO2 (<95%)
- Changes in blood pressure (<90/60 mmHg or >140/90 mmHg)
- Tachycardia/Bradycardia (>100 beats per minute, or <50 beats per minute)
- Abnormal increase in body temperature (>37.2 C)
- Dyspnoea
- Marked fatigue
- High intensity headache
- Balance disorders
- Retrosternal pain
- Severe cough
- Blurred vision
- Vertigo
- Feeling of palpitations
- Deep sweating (***, 2020; Matcovschi et al., 2011); (4)

Conclusions

1. SARS-CoV-2 infection can affect various organs and systems - respiratory, neurological, cardiac, ocular, gastrointestinal and other systems, having a strong impact on the functionality of affected patients, and in the long term it could cause various disabilities.

2. The severity and incidence of dysfunctionality and disability secondary to SARS-CoV-2 infection are still unknown, but early research suggests that these patients

will need rehabilitation at all stages of the disease - acute, post-acute and long-term.

3. The integrated medical rehabilitation service with the care of patients with SARS-CoV-2 of ers advantages both for the patient and for the medical system in general.

4. Numerous clinical trials provide recommendations on interventions and principles for the organization of rehabilitation care for this category of patients.

5. The objectives of post-COVID-19 medical rehabilitation are to improve joint mobility, increase endurance and muscle strength, improve breathing, re-educate balance, correct swallowing disorders, adapt to exertion, re-educate ADLs, achieve functional independence, return to social, professional and recreational activities.

6. Functional evaluation of the patient who has undergone COVID-19 infection is performed by specialized medical rehabilitation clinical examination using accessible, easily applicable tests without overloading the patient and without additional costs.

7. Rehabilitation of pulmonary and extrapulmonary sequelae after COVID-19 includes kinesiotherapy, electrotherapy and balneotherapy programs, individualized for each patient.

8. Post-COVID-19 rehabilitation can be carried out at all levels: hospital, outpatient and home, including the use of telemedicine.

Conf icts of interests

The authors have no conf icts of interests.

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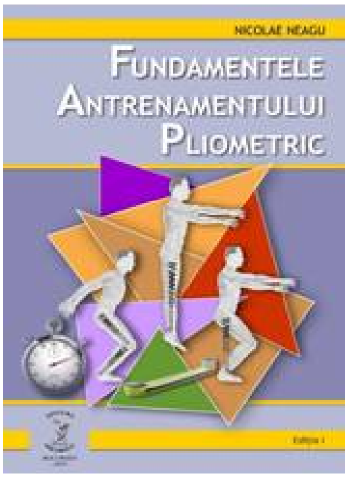
RECENT PUBLICATIONS

Book reviews

Fundamentals of plyometric training
Author: Nicolae Neagu
Publisher: Discobolul Publishing House, Bucharest, 2018
University format (18/25 cm), 423 pages



The book elaborated by the distinguished Prof. Dr. Neagu Nicolae Emilian falls, through the content of the issues addressed, in the field of the training methodology for athletes, and approaches *plyometric training* in an inter- and transdisciplinary manner, where theory does not appear as a goal per se, but helps in understanding the complex mechanisms of plyometrics as a method with optimizing and potentiating influences on individual sports performance.

Published by the Discobolul Publishing House @ Copyright 2018, the volume *Fundamentals of plyometric training* comprises a total number of 423 pages and 4 extensive chapters structured in 60 subchapters, 147 figures, 22 tables and a generous lexicon in which the reader is offered explanations of the terms used.

Chapter I highlights the concept of *plyometric training*, its evolution and defining notes; individual physical and mental engagement, the relationship of plyometrics with strength and speed training, the work regimens and the forces involved, the goals pursued through this type of training, the synergistic muscle relationships in plyometric training.

Chapter II presents the human body as a topological system, the relationships of the human body and Newton's mechanical principles; human locomotion, body symmetrization and elimination of bilateral body deficit; terms specific to mechanical physics in relation to the oscillations of physical systems or bodies; the human body as a self-oscillating biomechanical system; the levers of the human body, the lever system in sports situations; the movements of the body and body segments, from a biomechanical perspective.

Chapter III deals with a series of aspects regarding collision with the working surface and object, from a plyometric perspective; plyometrics in relation to integrated neuromuscular training and proprioceptive neuromuscular facilitation; controlled stretching in plyometric training, ballistic stretching, proprioceptive neuromuscular facilitation stretching, isostatic stretching; dynamic stretching, effects monitored by applying controlled stretching, short-term, medium-term and long-term effects, and recommendations regarding their use in training programs.

Chapter IV presents the muscular system and plyometric training: a brief incursion into myology, criteria regarding the morphological and structural typology of skeletal muscles; functional typology of skeletal muscles; topographic elements of skeletal muscles; fundamental properties of somatic muscles, electrical manifestations of muscle contraction; chemical manifestations with the stages of anaerobic and aerobic energy mechanisms; mechanical manifestations of muscle contraction: the contraction force of a skeletal muscle, absolute contraction force, relative contraction force, relative contraction force in relation to body weight, individual contraction force coefficient, relative contraction force in relation to other body segments and to the duration of execution and power; mechanical work; power; weight of a body; thermal and acoustic manifestations of muscle contraction.

Through this book written in several distinct and complementary registers, *informative-explanatory*, by introducing into the scientific circuit fundamental theories and concepts related to plyometric training, *critical-evaluative*, by presenting this type of training corroborated with some observations that help in optimizing the training methodology, and not least, *epistemological-methodological*, the author manages to increase awareness about and demonstrate the complexity of a profession that involves a level of interdisciplinary training beyond unipersonal empiricism and motivation.

This volume is extremely important for the field of motor activities in general and for high performance sport in particular through the informational support made available to scientific users, as well as by the way of addressing issues submitted to analysis and scientific interpretation. The critical and objective spirit, the accuracy, the dynamics and the coherence of ideas confer this book idea fluency, epistemological and praxiological balance.

Through its theoretical and didactic utility, and especially through its argumentative, scientific support, the volume *Fundamentals of plyometric training* elaborated by Prof. Dr. Nicolae Neagu is an asset of sports theory in Romania, as a reference book for specialists working in the field of human motor function.

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FOR THE ATTENTION OF CONTRIBUTORS

The subject of the journal

The journal has a multidisciplinary nature oriented toward biomedical, health, exercise, social sciences f elds, applyable in activities of physical training and sport, so that the dealt subjects and the authors belong to several disciplines in these f elds. The main rubrics are: “Original studies” and “Reviews”.

The Journal is aimed at adapting the prof le of the journal to scientif c contemporaneity in the f eld of medical and pharmaceutical sciences and interdisciplinary integration with health, physical activity and biopsychosocial rehabilitation.

The journal will have the same contents: editorials, original articles, review articles, case reports, recent publications, events. The journal is open for publication to all members of the national and international scientif c community and of ers the possibility to promote young people involved in research, along with top researchers in the above mentioned f elds.

Regarding “Reviews” the main subjects that are presented are: oxidative stress in physical ef ort; mental training; psycho-neuroendocrinology of sport ef ort; physical culture in the practice of the family doctor; extreme sports and risks; emotional determinatives of performance; the recovery of patients with spinal column disorders; stress syndromes and psychosomatics; olympic education, legal aspects of sport; physical f tness/exercise in the elderly; psychomotricity disorders; high altitude sportive training; f tness; biomechanics of movements; EUROFIT tests and other evaluation methods of physical f tness; adverse reactions of physical f tness; sport endocrinology; depression in sportsmen/women; classical and genetic drug usage; Olympic Games etc.

Among articles devoted to original studies and researches we are particularly interested in the following: the methodo¬logy in physical education and sport; inf uence of some ions on ef ort capacity; psychological prof les of students regarding physical education; methodology in sport gymnastics; the selection of performance sportsmen.

Other articles approach particular subjects regarding dif erent sports: swimming, rhythmic and artistic gymnastics, hand¬ball, volleyball, basketball, athletics, ski, football, f eld and table tennis, wrestling, sumo.

The authors of the two rubrics are doctors, professors and educators, from universities and preuniversity education, trai¬ners, scientif c researchers etc.

Other rubrics of the journal are: the editorial, editorial news, reviews of the latest books in the f eld and others that are presented rarely (inventions and innovations, universitaria, preuniversitaria, forum, memories, competition calendar, portraits, scientif c events).

We highlight the rubric “The memory of the photographic eye”, where photos, some very rare, of sportsmen in the past and present are presented.

Articles signed by authors from the Republic of Moldova regarding the organization of sport education, variability of the cardiac rhythm, the stages of ef ort adaptability and articles by some authors from France, Portugal, Canada must also be mentioned.

The main objective of the journal is highlighting the results of research activities as well as the permanent and actual dissemination of information for specialists in the f eld. The journal assumes an important role regarding the achievement of necessary scores of the teaching staf in the university and pre university education as well as of doctors in the medical network (by recognizing the journal by the Romanian College of Physicians), regarding didactic and professional promotion.

Another merit of the journal is the obligatory publication of the table of contents and an English summary for all articles. Frequently articles are published in extenso in a language with international circulation (English, French).

All the content of the journal is available immediately upon publication and is Open Access.

The Editorial Board of the Health, Sports & Rehabilitation Medicine journal informs its collaborators and readers that access to the journal is open and free. The journal does not have article processing or submission charges.

The journal is published quarterly and the works are accepted for publication in English language. The paper is sent by e-mail at the address of the editorial staf . The works of contributors that are resident abroad and of Romanian authors must be mailed to the Editorial staf at the following address:

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Objectives

Our intention is that the journal continues to be a route to highlight the research results of its contributors, especially by stimulating their participation in project competitions. Articles that are published in this journal are considered as part of the process of promotion in one’s university career (accreditation that is obtained after consultation with the National Council for Attestation of Universitary Titles and Diplomas).

We also intend to encourage the publication of studies and research, that include original relevant elements especially from young people. All articles must bring a minimum of personal contribution (theoretical or practical), that will be highlighted in the article.

In the future we propose to accomplish criteria that would allow the promotion of the journal to superior levels according international recognition.

THE STRUCTURE AND SUBMISSION OF ARTICLES

The manuscript must be prepared according to the stipulations of the International Committee of Medical Journal Editors (http://www.icmjee.org).

The number of words for the electronic format:

– 4000 words for original articles;

– 2000 words for case studies;

– 5000-6000 words for review articles.

Format of the page: edited in WORD format, A4. Printed pages of the article will be numbered successively from 1 to the f nal page.

Font: Times New Roman, size 11 pt.; it should be edited on a full page, with diacritical marks, double spaced, respecting equal margins of 2 cm.

Illustrations:

The images (graphics, photos etc.) should be numbered consecutively in the text, with arabic numbers. They should be edited with SPSS or EXCEL programs, and sent as distinct f les: „f gure 1.tif", „f gure 2. jpg", and at the editors demanding in original also. Every graphic should have a legend, written **under** the image.

The tables should be numbered consecutively in the text, with roman numbers, and sent as distinct f les, accompanied by a legend that will be put above the table.

PREPARATION OF THE ARTICLES

1. Title page: includes the title of article (maximum 45 characters), the name of authors followed by surname, work place, mail address of the institute and mail adress and e-mail address of the f rst author. It will follow the name of article in the English language.

2. Abstract: For original articles a summary structured like this is necessary: (Background, Aims, Methods, Results, Conclusions), of maximum 250 words, followed by 3-8 key words (if is possible from the list of established terms). All articles will have a summary in the English language. Within the summary (abstract) abbreviations, footnotes or bibliographic references should not be used.

Background, Aims. Description of the importance of the study and explanation of premises and research objectives.

Methods. Include the following aspects of the study: Description of the basic category of the study: of orientation and applicative. Localization and the period of study. Description and size of groups, sex (gender), age and other socio-demographic variables should be given. Methods and instruments of investigation that are used.

Results. The descriptive and inferential statistical data (with specif cation of the used statistical tests): the dif erences between the initial and the f nal measurement, for the investigated parameters, the signif cance of correlation coef cients are necessary. The specif cation of the level of signif cance (the value p or the dimension of ef ect d) and the type of the used statistical test etc are obligatory.

Conclusions. Conclusions that have a direct link with the presented study should be given.

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3. Text

Original articles should include the following chapters which will not be identical with the summary titles: *Introduction* (General considerations), *Hypothesis, Materials and methods* (including ethical and statistical informations), *Results, Discussions* results, *Conclusions* and suggestions. The conclusions should be formulated brief y, without comments extracted from the research, and numbered. Other type of articles, as orientation articles, case studies, Editorials, do not have an obligatory format. Excessive abbreviations are not recommended. The f rst abbreviation in the text is represented f rst in extenso, having its abbreviation in parenthesis, and thereafter the short form should be used.

Authors must undertake the responsibility for the correctness of published materials.

4. References

The references should include the following data:

For articles from journals or other periodical publications the international Vancouver Reference Style should be used: the name of all authors as initials and the surname, the year of publication, the title of the article in its original language, the title of the journal in its international abbreviation (italic characters), number of volume, pages.

Articles: Pop M, Albu VR, Vişan D et al. Probleme de pedagogie în sport. Educaţie Fizică şi Sport 2000; 25(4):2-8.

Books: Drăgan I (coord.). Medicina sportivă, Editura Medicală, 2002, Bucureşti, 2002, 272-275.

Chapters from books: Hăulică I, Bălţatu O. Fiziologia senescenţei. In: Hăulică I. (sub red.) Fiziologia umană, Ed. Medicală, Bucureşti, 1996, 931-947.

Starting with issue 4/2010, every article should include a minimum of 15 bibliographic references and a maximum of 100, mostly journals articles published in the last 10 years. Only a limited number of references (1-3) older than 10 years will be allowed. At least 20% of the cited resources should be from recent international literature (not older than 10 years).

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- the informed consent of adult subjects, patients and athletes, for their participation;
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certif cate from the Bioethical Committees, for animal study protocols.

The data will be mentioned in the paper, in the section Materials and Methods. The documents will be obtained before the beginning of the study. Will be mentioned also the registration number of the certif cate from the Bioethical Committees.

Editorial submissions will be not returned to authors, whether published or not.

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