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ORIGINAL STUDIES

Warm-up routines: performance assessment following both an active and a combined method in basketball players

Cristian Graur[1], Ștefan Adrian Martin[2], Roxana Maria Hadmaş[3]
[1] *Human Movement Sciences Department, University of Medicine, Pharmacy, Science and Technology Târgu Mureș, Romania*
[2] *Physiology Department, University of Medicine, Pharmacy, Science and Technology Târgu Mureș, Romania*
[3] *Food and Nutrition Hygiene Department, University of Medicine, Pharmacy, Science and Technology Târgu Mureș, Romania*

Abstract

Background. Warm-up is defined as a minimum exercise which increases body temperature along with both heart rate and respiratory frequency.

Aims. Our objective was to test individual performance during Squad Jump, Stiffness, and Fifteen seconds Vertical Jump Tests based upon the warm-up protocol.

Methods. Ten (n=10) competitive male basketball players were included in the study group. The study methodology consisted of three different tests during the specific pre-warm-up routine (C_1) and general, non-specific (C_2) warm-up routine, while monitoring: Flight Time (F_t), Contact Time (C_t), Target Center along with Power Ratio over Squad Jump, Stiffness, and Fifteen seconds Vertical Jump Tests.

Results. During C_1, STFt, Ct was lower (-0.094%) as against C_2 value (-0.16%), whereas Ft was similar, describing positive changes during C_1 (0.019%) and a drop during C_2 (-0.16%). Yet, Target Center reached 0.040% improvement over C_1, with a -0.153% drop upon the first repetition during C_2; Power Ratio changed by 0.175% and -0.116% during C_1 unlike C_2. Over C_2, unlike C_1, improved C_t, F_t, Power Ratio and Target Center were obtained due to an increased exercise complexity, through both static and dynamic exercises.

Conclusions. Over C_2, unlike C_1, improved C_t, F_t, Power Ratio and Target Center were obtained due to an increased exercise complexity, through both static and dynamic exercises. However, as seen through overall performance analysis, warm-up volume and intensity can decrease individual performance by minimizing the progress monitored over a linear anaerobic exercise.

Keywords: basketball, warm-up, power ratio, performance.

Introduction

Warm-up routines are performed with specific objectives during physical training. Of them, injury risk reduction while improving individual performance through enhanced functional adaptation is of particular importance (Gogte et al., 2017). Several methods failed to identify differences over a short term period in recreational athletes (McCrary et al., 2015). Each routine is adapted to exercise specificity, whereas differences can be seen between basketball, handball, football, cycling, etc. (Silva et al., 2018).

In team sports, warm-up routines consist of both static and dynamic movement during 5 to 30 minutes time. The activity within consists of individual *active*, *passive* or *combined warm-up* methods. During passive routines, as part of physical training, several functional changes can be reported (Gogte et al., 2017). One of them is related to injury risk management through both intrinsic and extrinsic factors. Intrinsic factors are described by Frikha et al. (2016) as past injuries, physical anomalies, body weight, sex and age; extrinsic factors are related to the training volume, intensity, training surface, equipment and technique. Warm-up methods tend to reduce extrinsic injury risk factors, through both active and passive methods which effect flexibility, strength and speed along with resistance.

As described by several authors, passive warm-up can increase oxygen release, improving metabolism activity and nerve conduction velocity, while influencing strength, speed, flexibility and coordination (Bishop, 2003a; Bishop, 2003b; Gogte et al., 2017). Still, active methods have different outcomes. According to Samson et al. (2012), increased blood flow, respiratory frequency and heart rate represent normal involuntary changes during active warm-

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Address for correspondence: University of Medicine and Pharmacy, Târgu Mureş, Gheorghe Marinescu Str. No.38, 540139, Romania
E-mail: martinstefanadrian@gmail.com
Corresponding author: Martin Ștefan Adrian, martinstefanadrian@gmail.com
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up methods, with influence on lactate metabolism and its use during specific or general exercise (McGowan et al., 2015).

Warm-up activities are described in several papers as a minimum exercise which increases body temperature, along with both heart rate (HR) and respiratory frequency (Rf). Yet, several applied methods can induce warm-up with less thermal effect, as seen in passive warm-up routines. The specific routines applied are important in order to increase individual adaptation during exercise. In early times, Gray et al. (2002) confirmed that active warm-up routines have an important role in ATP production, enhancing acetylcarnitine concentration while improving O_2 uptake and limiting lactate accumulation. However, these changes are dependent upon exercise capacity, specificity and volume as well as on warm-up intensity. In the paper of Takizawa et al. (2018), the final outcome regarding individual performance failed to change during passive unlike active warm-up routine.

Several warm-up routines are performed through combined methods. These are characterized by an altered ratio between active and passive methods (Andrade et al., 2015). Basketball represents a complex team sport in which the outcome is dependent upon both technical and tactical actions (Pliauga et al., 2015; Ziv & Lidor, 2010).

Hypothesis

Based on our hypothesis, during exercise, individual adaptation can be altered in relation to the physical or technical objective within the programmed activity, while influencing force development, coordination and balance.

Objectives

Our objective was to test the current hypothesis by conducting three different tests during specific pre-warm-up routine and general, non-specific, warm-up routine, while monitoring: Flight Time, Contact Time, Target Center along with Power Ratio over Squat Jump, Stiffness, and Fifteen seconds Vertical Jump Tests.

Material and method

Research protocol

We conducted a cross-sectional study on a group of professional basketball players with competitive national senior activity. In order to apply the study methodology, an oral and written consent was obtained from (I.) athletes, (II.) club management, along with (III.) the University Ethical Committee.

a) Period and place of the research

The study was conducted during February - March 2019, in Târgu Mureș, Romania.

b) Subjects and groups

The study group consisted of 10 competitive basketball players with a reported mean age of 23.6±4.45 years, 192.1±9.19 cm height and 91.9±15.56 kg body weight. In order to be included in the study group, the athletes had to meet the following inclusion criteria: (I.) male basketball player with (II.) general medical acceptance (III.) currently competing at national professional level. The exclusion criteria were: (I.) medical incompatibility with the pre-determined training program or testing program, (II.) health condition/s preventing the study activity or individual health.

c) Tests applied

The study was conducted over seven (n=7) days. The mentioned period was divided into two conditions, described as Condition 1 (C_1) and Condition 2 (C_2). Each condition (C_1 – C_2) represented a different warm-up protocol, the outcome of which was tested by using three physical tests (n=3), applied one single time while measuring four main (n=4) parameters: Flight time (s), Contact Time (s), Target Center (cm) along with Power Ratio (W/ kilo).

Warm-up protocol during C_1 and C_2

C_1 was conducted during the first training of the day, after 12 hours recovery time and 24 hours low-intensity training. During C_1 the warm-up length was 8 minutes, by applying the following exercises: (1) 3 minutes running with the basketball ball between the 2 baskets and (2) 5 minutes continuous run on half of the court with a lay-up finish each time (3); C_2 was applied 48 hours after C_1, in similar conditions. The warm-up length increased while conducting the following exercises: (1) 3 minutes running along the court, (2) Dynamic stretching over half of the court (x8 repetitions), (3) 6 minutes static stretching (gymnastics), (4) Running exercises up to half the court by performing Forward Lunges, High Knees, Butt Kicks, Carioca (2x).

Performance measurement tests

Due to both C_1 and C_2 warm-up methods conducted 48 hours apart, three specific tests were applied to assess individual performance: (1) Squat Jump Test (SJt), (2) Stiffness Test (STFt) and (3) Fifteen seconds Vertical Jump Test (15sJt). The tests were performed by using the OptoJump System device (Microgate, Bolzano, Italy), each lasting according to the testing methodology. During all three tests, the parameters of interest were: Flight Time (F*t*, seconds), Contact Time (C*t*, seconds), Target Center (cm) and Power Ratio (Watt per kilo, W/kilo), as seen in Fig. 1.

Testing was conducted in similar environmental conditions, 20°C environmental temperature, 70% humidity. To conduct the tests, the subjects positioned themselves between the two arms of the OptoJump System device. The tests were carried out successively with a 2 minute pause between them, while respecting the following order: (I.) *SJt,* (II.) *STFt* and (III.) *15sJt*; the testing principle evolved from low towards an increased testing volume. During each repetition, the device recorded the parameters of interest. Monitoring was performed in real time, stored and further analyzed.

SJt objective was to evaluate explosive force, over one single jump (n=1) starting from a Squat position, with the arms placed on the hips, legs wide apart with no counter movements. *STFt* objective was to evaluate reactive force by performing seven consecutive jumps (n=7) while maintaining the knees straight. The starting position was similar to SJt, the arms placed on the hips and the legs close apart. *15sJt* objective was to measure anaerobic power over 15 seconds of continuous exercise. Several jumps were executed during 15 seconds time by starting the test from a standing position and performing successive jumps with the arms placed on the hips, legs wide apart and no counter movements.

d) Statistical processing

SPSS 20 software was used in order to analyze the current data. The level of significance was pre-set at α=0.05. Normal distribution was assessed by using Shapiro-Wilk test, whereas descriptive data are illustrated such as mean±SD. The paired samples T test was used in order to identify the main changes between C_1 and C_2.

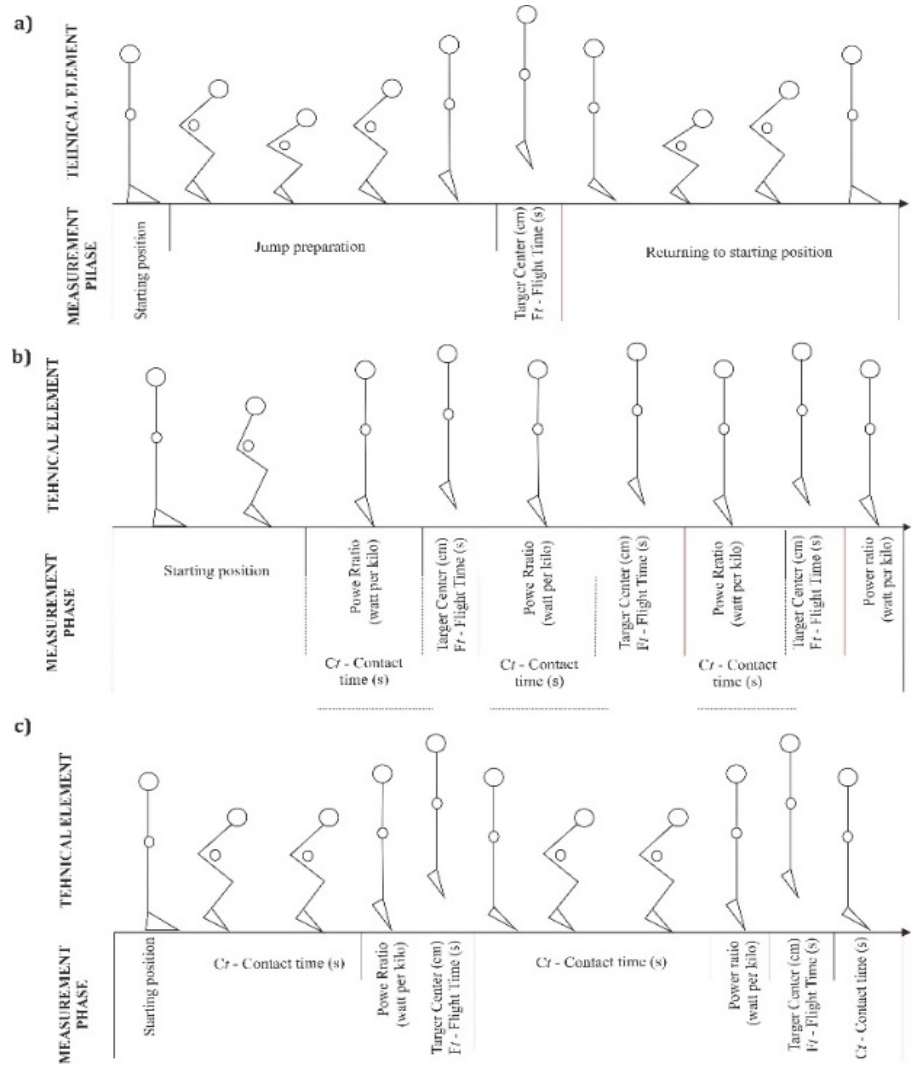

Fig. 1 – Graphic representation of the performance evaluation methods: (a.) SJt, (b.) STFt and (c.) 15sJt
Note: SJt = Squat Jump Test; STFt = Stiffness Test; 15sJt = Fifteen seconds Vertical Jump Test.
Before each test, the athletes resumed the testing methodology in order to avoid any pauses during exercise and to comply with the main technical regulations.

Results

A mean body weight of 91.9±15.56 kg and a mean height of 192.1±9.19 cm were measured in the study group. General performance over both C_1 and C_2 was described through F*t*, C*t*, Target Center, along with the Power Ratio, as seen in Table I. Of the three tests, SJt failed to include C*t* and Power Ratio measurements due to one single jump as against STFt and 15SJt protocols, which consisted of several jumps over a different period length.

Ct changes over C_1 and C_2

C*t* changes were measured over STFt and 15sJT tests, but not SJt. During C_1, STFt, C*t* mean value was 0.21 s, whereas over 15sJT, the value reached 0.54 s, as seen in Fig. 2.

Table I

General performance illustration over both C_1 and C_2 measurements, during SJt, STFt, 15sJt.

Performance parameters	Mean value ±SD		
	SJt	STFt	15sJt
C*t*	-	0.21±0.02	0.54±0.06
F*t*	0.57±0.03	0.50±0.05	0.49±0.04
Target center	40.75±4.72	31.8±7	31.21±4.79
Power ratio	-	42.41±9.71	23.56±2.91

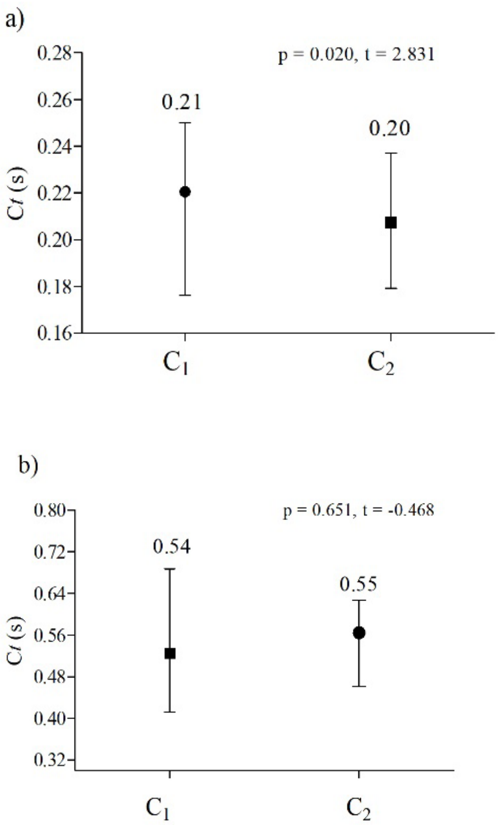

Fig. 2 – C*t* differences over C_1 – C_2, during STFt (a.) and 15sJT (b.), represented as mean values

Significant statistical changes resulted between C_1 and C_2 regarding C*t* value, during STFt, C_2 (p = 0.020), whereas during 15sJT, C_2, performance reached a higher value, without a significant difference (p = 0.651), as illustrated in both Fig. 2. and Table II.

F*t changes over C_1 and C_2*

F*t*, as against C*t*, was measured during all three tests. Using the C_1 and C_2 methods, significant differences were identified. F*t*, during SJT, over C_1, reached a mean value of 0.55 s, whereas during C_2, a mean value of 0.59 s was found (p = 0.01). Similar results were obtained over STFt, 0.46 s. vs. 0.54 s. mean values (p = 0.01) between C_1 and C_2, whereas during 15sJT, 0.46 s vs. 0.52 s (p = 0.01) were recorded, as detailed in Table III.

Target Center changes over C_1 and C_2

Similarly to Ft, Target Center was measured during all three tests. Differences were monitored during both C_1 and C_2 warm-up protocols. During C_1 stage, SJt Target Center reached 38.14 cm, while 43.36 cm was the mean value for C_2 (p = 0.01) warm-up method. Further on, the same parameter, over STFt, reached 27.07 cm during C_1, with a significant difference (p = 0.01) for C_2 measurement, 36.68 cm. Similar changes were monitored during 15sJT test, as detailed in Table IV.

Table II

C*t* statistical differences over C_1 – C_2, during STFt (a.) and 15sJT (b.)

Test type	**Ct (mean±SD)**		**p**	**t**	**95% CI**	
	C_1	**C_2**			**Lower**	**Upper**
STFt	0.21±0.02	0.20±0.02	0.020**	2.83	0.001	0.017
15sJt	0.54±0.08	0.55±0.04	0.651*	-0.46	-0.061	0.040

Table III

F*t* statistical differences over C_1 – C_2, during SJt, STFt and 15sJT tests.

Test type	**Ft (mean±SD)**		**p**	**t**	**95% CI**	
	C_1	**C_2**			**Lower**	**Upper**
SJt	0.55±0.3	0.59±0.02	0.0001**	-5.806	-0.512	-0.022
STFt	0.46±0.04	0.54±0.03	0.0001**	-6.217	-0.106	-0.049
15sJt	0.46±0.02	0.52±0.03	0.0001**	-8.401	-0.074	-0.042

Table IV

Target Center statistical differences over C_1 - C_2, during SJt, STFt and 15sJT tests.

Test type	**Target Center (mean±SD)**		**p**	**t**	**95% CI**	
	C_1	**C_2**			**Lower**	**Upper**
SJt	38.14±4.12	43.36±3.85	0.0001**	-5.99	-7.189	-3.250
STFt	27.07±5.31	36.68±5.23	0.0001**	-6.40	-12.99	-6.21
15sJt	43.36±3.85	34.75±3.65	0.0001**	-4.18	-5.24	-1.55

Table V
Statistical differences regarding Target Center over C_1 – C_2, during STFt and 15sJT tests

Test type	Target Center (mean±SD)		P	t	95% CI	
	C_1	C_2			Lower	Upper
STFt	36.08±6.34	48.75±8.35	0.0001	-7.32	-16.58	-8.75
15sJt	21.86±2.22	25.26±2.55	0.002	-4.18	-5.24	-1.55

Table VI
Performance reduction in successive activities, illustrated as mean±SD data, for both C_1 and C_2 methods

Test type	Parameters of interest	Mean value±SD		p	t	95% CI	
		C_1	C_2			Lower	Upper
STFt	F*t*, s	0.05±0.07	-0.12±0.08	0.0001	6.489	0.116	0.240
	C*t*, s	-0.08±0.11	-0.16±0.10	0.197	1.394	-0.461	0.194
	Target Center, cm	0.11±0.16	-0.10±0.12	0.002	4.411	0.103	0.320
	Power Ratio, w/kilo	0.16±0.15	-0.08±0.12	0.0001	5.248	0.145	0.364
15sJt	F*t*, s	0.01±0.08	2.60±8.30	0.350*	-0.986	-8.529	3.352
	C*t*, s	-0.07±0.21	0.04±0.18	0.235	-1.273	-0.331	0.092
	Target Center, cm	0.03±0.18	-0.05±0.15	0.280	1.149	-0.083	0.257
	Power Ratio, w/kilo	0.11±0.22	-0.05±0.08	0.046	2.309	0.003	0.351

Power Ratio changes over C_1 and C_2

During STFt, the mean power reached 36.08 W/kilo, while a value of 21.86 W/kilo was measured over 15sJt, as illustrated in Fig. 3. In comparison, during C_2, significant changes were measured on both STFt Power Ratio: 48.75 W/kilo ($p = 0.01$) and 15SJt Power Ratio: 25.26 W/kilo ($p = 0.02$) (Table V).

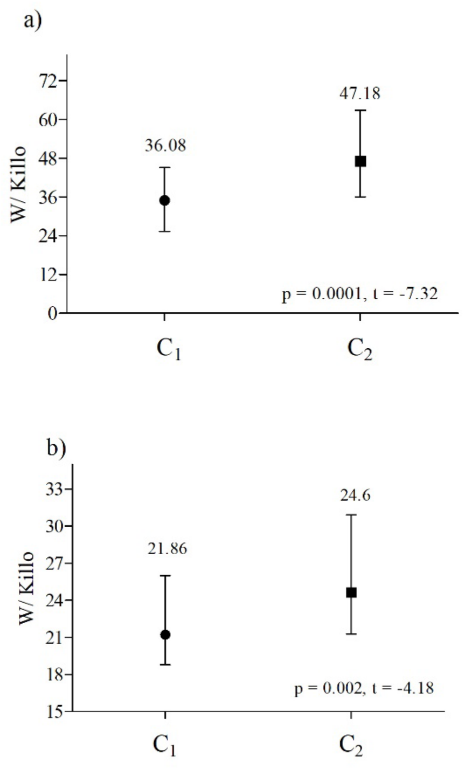

Fig. 3 - Power Ratio differences over C_1 - C_2, during STFt (a.) and 15sJT (b.), represented as mean values

Overall performance during C_1 - C_2

Overall performance was detailed for C_1 and C_2 warm-up methods. The following analysis was performed by measuring performance reduction in successive repetitions during: STFt and 15sJt tests (Table VI). During C_1, STFt, Ct was lower (-0.094%) as against C_2 value (-0.16%), while Ft was similar, describing positive changes during C_1 (0.019%) and a drop during C_2 (-0.16%). Yet, Target Center reached a 0.040% improvement over C_1, with a -0.153% drop upon the first repetition during C_2; Power Ratio changed by 0.175% and -0.116% during C_1 unlike C_2. Different measurements were obtained in 15 sJt test for Ft (-0.007 vs. -0.056%), Ct (-0.036 vs. 0.062%), Target Center (-0.130 vs. -0.117%) and Power Ratio (0.154 vs. -0.069%) during C_1 as against C_2 ($p>0.05$).

Discussion

Following the study methodology, both warm-up protocols were dynamic, taking into account the level of active exercise. The main objective over C_1 and C_2 was to improve individual adaptation following the specific performance jump test. The C_1 as against C_2 method limited F*t* ($p = 0.01$), Power Ratio ($p = 0.01$), Target Center ($p = 0.01$) and C*t* ($p = 0.20$). Yet, exercise continuity, based on the study methodology, described a performance drop starting from the first measurement of each test during C_1 as against C_2,

Active warm-up methodology conducted through C_1 and C_2

Similarly to other research papers conducted with a similar objective, exercise intensity has a major impact upon individual adaptation and warm-up objective (Bishop, 2003a; Fradkin et al., 2010). An important inter-individual variability was reported by the study of both female and male athletes (Monteiro et al., 2016). Anywise, in both groups, the main outcome based on active warm-up methods is an increased blood flow, which can increase both respiratory frequency and heart rate, improving lactate metabolism, as seen in the study of Wahl et al. (2010). Taking into account our methodology, both conditions (C_1 and C_2) included running, while inducing similar functional changes. Yet, the final result was different, with an improved activity result due to C_2 as against C_1 method. Similar results were identified, but only using passive as against active warm-up methods, concluding that high oxidative ATP is obtained through warm-up at the start of the main training activity (Gray et al., 2001). Avelar et al. (2012) distinguished the following methods and objectives focusing on injury prevention, unlike our objective involving individual performance parameters.

According to Wahl et al. (2010), the use of external devices can be taken into account to ensure optimal warm-up and improve anaerobic performance. In our methodology, no device was used to improve individual performance. Anywise, it will be important to characterize individual progress along the main training activity following such a warm-up method, taking into account that Park et al. (2018) proved in their work that free weight warm-up can improve individual performance. According to O'Sullivan et al. (2009), the warm-up protocol should be both general and specific to the individual field position. Stevanovic et al. (2019) studied specific movement along the court, but failed to identify differences of the used methods compared to our non-specific field position outcomes.

Pagaduan et al. (2012) brought into discussion the use of speed during warm-up routines, similar to our protocol. However, as a result of both static and dynamic methods, sprint time failed to change, whereas an improvement was obtained due to static warm-up, unlike our results in which combined warm-up methodology, during C_2, improved the main anaerobic parameters. In the study of Kendall et al. (2017), an important change in anaerobic performance following static warm-up compared to no warm-up routine was obtained. Still, individual progress failed to be measured through overall performance, while claiming that static routines are important following high-intensity exercise.

Several papers which used exercise as a performance indicator followed a different methodology. In specific basketball activity, power is an important parameter studied, as shown in both our papers and several other publications (Gonzalez et al., 2013; Pojskić et al., 2015; De Sousa Fortes et al., 2018). Yet, different results were obtained taking into account that basketball has several technical elements which are dependent upon power. According to Bishop (2003b), static activity can improve power ratio, while our study protocol consisted of a combined warm-up protocol, during C_2. McMillan et al. (2006) reported an improved power due to a dynamic program, similar to our methodology, but different from other papers which failed to determine a performance improvement (Bishop & Middleton, 2013).

Overall performance

Physical performance following a warm-up method is important. Based on our results, individual performance can be insecure upon dynamic, anaerobic exercise. This state is proved through C_1 unlike C_2 improvement during the tests. Other publications failed to identify overall performance (Blazevich et al., 2018). A performance drop could be related to static warm-up routines (Blazevich et al., 2018), whereas in our study no similar methods were applied. However, C_2 intensity was similar to C_1 (75% HR_{max}), while exercise time was different, with an increased volume during C_2. We believe that C_2 volume was higher relative to intensity. Therefore, a drop in performance was obtained during C_2 unlike C_1, proven by F*t* (-0.08 vs. 0.03%), C*t* (-0.05 vs. -0.08), Power Ratio (-0.07 vs. 0.14%), along with Target Center (-0.07 vs. 0.07%) during STFt and 15sJt tests.

According to the available data, several methodology improvements are needed in order to conclude the current outcomes. Among them, the (I.) number of subjects, (II.) technical performance analysis, (III.) lactate measurement, (IV.) electromyography (EMG) use in order to assess muscle fiber activation and exercise intensity. In the current study, the mentioned methodology improvements are considered study limitations.

Conclusions

1. Over C_2, unlike C_1, an improvement in C*t*, F*t*, Power Ratio and Target Center was obtained due to an increased exercise complexity, through both static and dynamic exercises.
2. As shown by overall performance analysis, warm-up volume and intensity can decrease individual performance by minimizing performance during a linear anaerobic exercise.
3. Both warm-up volume and intensity seem to influence individual performance during specific or non-specific exercise.
4. In order to conclude the current findings and improve the use of various warm-up methods over individual adaptation, performance and injury risk, several methodology improvements are needed.

Conflicts of interest

The authors declare no conflict of interest.

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