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Association between motivation and decision-making in under-18 male volleyball players

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Abstract
Introduction. **Motivation and decision-making are important variables of sports performance. In this perspective, identifying whether motivation is associated with decisions made by athletes is essential to provide environments that facilitate the achievement of better performances.** Aim of Study. **The objective was (a) to analyze the decision-making and levels of motivation among male under-18 volleyball athletes with different levels of experience; and (b) associating motivation and decision-making in different game situations (attack from central and court extremities, setting, and blocking).** Material and Methods. **In the study, 92 high-performance male volleyball athletes from the under-18 category were divided into two groups: more experienced group (G1) and less experienced group (G2). The motivation level was analyzed by the Sport Motivation Scale-II, and the Declarative Tactical Knowledge Test in Volleyball was used to analyze the decision-making.** Results. **The results revealed a positive, but weak and significant correlation between the attack from the extremity and integrated motivation, and among intrinsic and introjected and external motivation. There was also a positive, moderate, and significant correlation between introjected and external motivation. Besides, G1 showed less intrinsic, introjected, and external motivation when compared to G2. Regarding decision-making, G1 showed higher values for central attack and lower values for setting and blocking, when compared to G2.** Conclusions. **It is concluded that better decisions of under-18 volleyball athletes in situations of attack from extremity are associated with a higher occurrence of integrated (extrinsic) motivation and more experienced volleyball athletes have a prevalence of intrinsic and extrinsic motivation when compared to less experienced athletes.**

KEYWORDS: cognition, sport psychology, sports training, young athletes, team sports.

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Introduction

Motivation is one of the psychological issues widely studied in the field of sports sciences, as it is identified as a key element in sports practice, influencing results in competitions and promoting better conditions for training and athletes' performance [24, 28]. The self-determination theory is one of the theories that try to elucidate motivation. Proposed by Ryan and Deci, it suggests that an individual can be regulated by different types of motivation (intrinsically or extrinsically), or even be amotivated during the practice of any activity. According to self-determination theory (SDT) [13], autonomous (or self-determined) forms of motivation are the result of satisfaction of the basic psychological needs of autonomy, competence, and relatedness. When people act in self-determined ways, they act out of personal value, importance, and interest and are free to regulate their behaviors accordingly [12]. It is influenced by situations and experiences already experienced and by the emotional state of the individual [12, 13].

The extrinsic motivation, on the other hand, is that which occurs when an activity is carried out with a purpose other than that inherent to the person himself, that is, when the individual is influenced by external factors in the performance of his activities. In this manifestation of motivation, the subject seeks external or social rewards, such as receiving praise and rewards, or even avoiding punishment. The amotivation state, on the other hand, is defined by the lack of intention to act [13].

The most common reasons for sports participating in young people are related to fun and a path for striving to achieve their goals alongside friends, meet new people and try to improve their physical condition [25]. Thus, some factors must be considered when analyzing the athletes' motivation to sports practice, as there are benefits associated with sports practice in adolescence. In this context, understanding how motivation alters young people's adherence and maintenance for the sports practice, as well as maintaining or improving performance, may promote the individual's long-term commitment to the sport, helping parents, coaches and teachers in sports context [29].

Besides, previous studies have found that motivations are related to many variables, such as good performance in the training and competition process [7], persistence in sport [16], success and well-being [5, 21], and the athlete's mental health [28]. Therefore, improving the individual to practice a certain sport is essential for the athlete to make the best decisions [3, 7]. In this context, decision-making (DM) is an important factor related to performance in team sports [4, 23, 26], as it refers to the process of choosing among a set of options, it is crucial to previously consider the consequences of the choice [22], and is shown to be influenced by the motivation for sports practice [7].

Moreover, training in team sports should provide the opportunity for the regulation of intentional actions, directed to the specific objective of the game [19]. This form of training arouses greater motivation in the athlete and therefore, should be considered in the teaching-learning-training process [27].

In this perspective, identifying whether motivation is associated with decisions made by athletes is essential to provide environments that facilitate the achievement of better performances. However, studies that contain information about this relationship are scarce in volleyball and other team sports [23].

Aim of Study

Given this, the present study has two objectives: (a) to analyze the decision-making and levels of motivation regulation among male under-18 volleyball athletes with different levels of experience, and (b) associating motivation and decision-making in different game situations (attack from central and extremity, setting and blocking). From a practical point of view, clarifying this relationship may help volleyball teams to create strategies that allow optimizing the performance of athletes in training and competitions.

Material and Methods

Sample

The sample was composed of 92 high-performance male volleyball athletes of the under-18 category in Brazil, divided into two groups (more experienced group – G1, and less experienced group – G2), according to the experience in the sport, i.e., the time they competed and the level of competitions played. So, Group 1 was

Table 1. Sample characteristics (mean and standard deviation)

	N	Age (yrs)	Volleyball experience (yrs)	Training sessions by week	Training session duration (min)	Experience in competition (yrs)	Level of competitions played
G1	46	17.2 (± 1.4)	5.0 (± 1.2)	4.9 (± 0.9)	174.7 (± 43.9)	4.8 (± 1.5)	regional, national and international
G2	46	16.6 (± 0.7)	3.8 (± 1.4)	5.0 (± 1.0)	150.0 (± 11.0)	3.6 (± 1.2)	regional, national

Note: G1 – more experienced group, G2 – less experienced group composed of athletes with 5 years or more of sports experience, and Group 2 was composed of athletes with less than 5 years of experience.

The approach to the athletes was made through the local volleyball federation, which provided the contacts to the teams who deal with the under-18 category. For inclusion in the study, the athletes had to perform the continuous practice of volleyball at least three times a week for a minimum period of one year, and compete for their clubs. To characterize the sample, a questionnaire of demographic data was applied, as used in other studies in that field [4, 15].

The groups' profiles are described in Table 1.

Instruments

Sport Motivation Scale-II (SMS-II)

To assess sports motivation, the Sport Motivation Scale (SMS) [20, 21] is the most used instrument, and, according to Clancy, Herring, and Campbell [6], it has the highest citation rate per year (19.5 citations/year) among the most important measures of motivation in sport. In the Brazilian sports context, SMS-II was subjected to cross-cultural adaptation, presenting an analysis of acceptable psychometric properties for practical use [18].

Thus, for the analysis of athletes' motivation, the SMS-II questionnaire was applied. Originally presented by Pelletier et al. [20, 21] now widely used in Brazil as a Sport Motivation Scale. The SMS-II consists of 18 items distributed in 6 subscales: intrinsic regulation, integrated regulation, identified regulation, introjected regulation, external regulation, and amotivation.

The intrinsic regulation is the satisfaction found to perform an activity. Integrated regulation is the most autonomous form of extrinsic motivation, and occurs when the behavior is not only seen as something of value, but is also considered consistent with other goals and needs of life. The identified regulation is described as the behavior interpreted as personally important and worthwhile. The introjected regulation is defined by actions directed to avoid feelings of pity and or guilt and shame. External regulation affects situations in which behavior is controlled externally by awards or penalties. Amotivation consists of a lack of intention to practice an activity.

Declarative Tactical Knowledge Test in Volleyball (DTKT:VB)

To assess the decision-making (DM) the Declarative Tactical Knowledge Test in Volleyball (DTKT:VB) was used [10]. The test consists of 24 real action game scenes and 4 types of game situations: extremity attack – EA (6 scenes), central attack – CA (6 scenes), setting – SET (6 scenes), and blocking – BL (6 scenes). The selected scenes' duration varied between 4 to 6 seconds and were taken from the top perspective, at 4 meters height and at an approximate distance of 7 to 9 meters from the bottom of the court, or that allowed the observer a total view of the court and depth perception in different situations.

During the test, when the scenes were interrupted, the screen became blank and the volunteer immediately had to verbalize what he would do to try to score in that specific situation. The answer was considered his DM.

The objective was to extract information related to the quality of DM (number of correct answers according to the test template), approaching the test to the maximum of the time in a real game situation. All responses were immediately noted by the assisting researcher. This test has already been used with youth volleyball athletes [4] and coaches [11].

The experimental approach to the problem

This study is classified as analytical and observational research, with a cross-sectional character. The first step was signing a consent form by the volleyball club's representative and the athletes' parents or legal guardians, which contained instructions and information about the research stages. Data collection comprised of filling the Sport Motivation Scale-II questionnaire [18] and performing the Declarative Tactical Knowledge Test in Volleyball [10] by included athletes. This study was approved by the University's Research Ethics Committee (CAAE: 87133417.3.0000.5149) and respected the standards established by the National Health Council and Declaration of Helsinki (2013).

The study took place in the pre-season. The individual appointments for data collection were scheduled in the morning before the training session (to reduce possible effects of daily fatigue), in a quiet and well-lit room at the training facility. Directly before, and during completing the tasks athletes did not have contact with each other.

Statistical analyses

The normality of data was tested by the Shapiro–Wilk test. Data were expressed as the median and interquartile range (IQR). To compare all variables, a Mann–Whitney test for independent samples was applied. Furthermore, Cohen's d was used to assess the effect size of comparisons [8]. The following classification to measure the magnitude of effect size was used: small, $d = 0.2$ to 0.49, moderate, $d = 0.5$ to 0.79, and large, $d > 0.8$. Spearman's correlation coefficient was applied to test for associations between the variables.

All procedures were carried out using Statistical Package for the Social Sciences (SPSS v21.0) for a $p < 0.05$.

Results

The more experienced group (G1) showed higher values in decision-making for the central attack, with small effect size, and lower values for setting and blocking compared to the less experienced group (G2) ($p < 0.05$), with great effect size. No statistical differences were found between the groups for the extremity attack ($p > 0.05$) (Table 2).

Besides, G1 reported lower intrinsic (moderate effect size), introjected (moderate effect size), and external (large effect size) motivation than G2 ($p < 0.05$). There were no differences ($p > 0.05$) between groups for integrated motivation (small effect size), identified (no effect), and amotivated (no effect) (Table 3).

Correlation analyzes showed a positive, weak and significant correlation ($r = 0.217$; $p < 0.05$) between extremity attack and integrated motivation. The central attack showed a negative, weak and significant correlation with the introjected motivation ($r = –0.208$; $p > 0.05$) and external ($r = –0.241$; $p < 0.05$). Positive, weak and significant correlations were found between setting and intrinsic ($r = 0.230$; $p < 0.05$), introjected ($r = 0.264$; $p < 0.05$) and external ($r = 0.277$; $p < 0.05$) motivation.

Table 2. Data on decision-making

	G1 (n = 46)	G2 (n = 46)	*p*-value	ES (classification)
Extremity attack	0.60 (0.50-0.65)	0.60 (0.50-0.80)	0.243	–0.167 (no effect)
Central attack	0.80 (0.60-1.00)	0.70 (0.60-0.80)	0.013*	0.465 (small)
Setting	0.50 (0.30-0.50)	0.60 (0.60-0.70)	0.001*	–1.564 (large)
Blocking	0.30 (0.10-0.42)	0.55 (0.50-0.80)	0.001*	–1.405 (large)

Note: Data presented as median and interquartile range (IQR); G1 – more experienced group, G2 – less experienced group, ES – effect size
* $p \leq 0.05$

Table 3. Sport Motivation Scale-II (SMS-II)

	G1 (n = 46)	G2 (n = 46)	*p*-value	ES (classification)
Intrinsic	6.7 (6.0-7.0)	7.0 (6.7-7.0)	0.019*	–0.515 (moderate)
Integrated	6.7 (5.3-7.0)	6.7 (6.3-7.0)	0.155	–0.402 (small)
Identified	6.3 (6.0-7.0)	6.7 (5.7-7.0)	0.543	0.046 (no effect)
Introjected	5.3 (4.3-6.0)	6.3 (5.7-7.0)	0.001*	–0.769 (moderate)
External	2.0 (1.3-3.0)	3.6 (2.3-5.0)	0.001*	–0.877 (large)
Amotivated	1.0 (1.0-1.7)	1.0 (1.0-1.3)	0.185	0.020 (no effect)

Note: Data presented as median and interquartile range (IQR); G1 – more experienced group, G2 – less experienced group, ES – effect size
* $p \leq 0.05$

Table 4. Matrix correlation beween more and less experienced players

	Intrinsic	Integrated	Identified	Introjected	External	Amotivated
Extremity attack	0.164 (0.118)	0.217 (0.038)*	0.137 (0.192)	0.142 (0.177)	0.270 (0.798)	–0.170 (0.873)
Central attack	–0.720 (0.497)	0.490 (0.642)	–0.390 (0.714)	–0.208 (0.047)*	–0.241 (0.021)*	–0.570 (0.588)
Setting	0.230 (0.028)*	0.195 (0.063)	0.091 (0.388)	0.264 (0.011)*	0.277 (0.030)*	–0.103 (0.328)
Blocking	0.153 (0.145)	0.187 (0.075)	0.089 (0.398)	0.403 (0.001)*	0.259 (0.013)*	–0.242 (0.020)*

Note: Data expressed as Spearman's coefficient *r* (*p*-value)
* $p \leq 0.05$

The blocking demonstrated a positive, moderate and significant correlation with the introjected ($r = 0.403$; $p < 0.05$) and external ($r = 0.259$; $p < 0.05$) motivation and a negative, weak and significant correlation with amotivation ($r = –0.242$; $p < 0.05$) (Table 4).

Discussion

The present study aimed to (a) analyze the decision-making and levels of motivation among male under-18 volleyball athletes with different time of experience; and (b) to associate motivation with decision-making in attack (extremity and center), setting, and blocking situations. The results revealed a positive, weak, and significant correlation between extremity attack and integrated motivation. Thus, perhaps the attack action is controlled motivationally by the objectives, goals, and needs that the athlete imposes. The results showed a positive, weak and significant correlation between intrinsic and introjected and external motivation, and a positive, moderate and significant correlation between introjected and external motivation, demonstrating that perhaps athletes direct their actions to avoid feelings of guilt or shame, avoiding possible punishments.

The more experienced group showed less intrinsic, introjected, and external motivation when compared to G2. This result can be explained by the desire to stand out in the sport, as the G2 athletes were less experienced than the G1 ones. It is also noteworthy that more experienced athletes already visualize the performance they have and know the real conditions to continue their sports career. This may have influenced the types of motivation presented by G1 in relation to G2.

Moreover, it is observed that the values of intrinsic motivation were higher in both groups when related to the values of extrinsic motivation. Such results corroborate with findings by Murcia, Gimeno, and Coll [17]. In a comparable context, they observed in young athletes the higher scores for intrinsic motivation when compared to extrinsic motivation. When evaluating 34 sub-19 volleyball athletes Claver et al. [7] observed that giving the athletes responsibility for different tasks related to the training process may help to increase the intrinsic motivation and autonomy. Additionally, Vella et al. [28] showed that self-determined forms of motivation (intrinsic motivation) were associated with better results in the mental health of young male athletes from different team sports.

Regarding decision-making, in the present study, the G1 had higher values for central attack and lower values for setting and blocking, when compared to G2. Studies conducted with volleyball athletes [1, 2, 4, 9, 26] analyzed the relationship between these variables and the sports experience. In general, the results showed that athletes with more experience in volleyball make better decisions in different game situations, which is not in accordance with the present study.

Research in youth categories has shown that athletes with higher skill levels in the same game category, try to be faster and more effective in their decision-making [14]. The more experienced players have more knowledge of the sport, which allows them to recognize game patterns, detect relevant information, and solve problems more effectively [9, 14, 26]. This difference between the results of the aforementioned studies and the present one can be explained by the little difference in the experience with systematized training and competition levels of athletes participating in this study.

Recent reviews in sports [23] recommend the use of decision-making interventions or training as part of, or complementary to, training to improve the decision-making, optimizing the ability to perceive and process relevant stimuli and then generate quick and effective responses. Additionally, motivation to practice sports is essential for the athlete to make the best decisions [3, 7]. Thus, the differences found between the groups may have occurred due to different training processes, a fact that affected the results, even though one group was more experienced than the other.

The present study has some limitations, such as the fact that the tests were performed only in the initial period of the yearly training plan, which does not allow us to extend the results for the whole season and different training situations. The information obtained through SMS-II and DTKT:VB, although validated and widely used with athletes, do not evaluate the possible interactions between motivation and decision-making, being limited to statistical inference. Finally, we did not investigate the history of athletes' training regimes.

However, the possibility of analyzing the interactions between motivation and decision-making should be seen as an important factor in helping professionals working in the sports environment and training planning. Thus, as a practical implication, the possibility of creating exercises and strategies that maximize individual and collective behaviors that can make the practice more motivating without reducing its applicability and tactical-technical effectiveness is recommended.

Conclusions

It is concluded, with the results of the present study, that better decisions of under-18 volleyball athletes in extremity attack situations are associated with a higher occurrence of integrated (extrinsic) motivation. Still, more experienced volleyball athletes have a lower prevalence of intrinsic and extrinsic motivation when compared to less experienced athletes. It is suggested that future studies be carried out in the long term, analyzing the variables at different times of the training season, in different categories, and competitive levels of volleyball.

Conflicts of Interest
The authors declare no conflict of interest.

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Indicators of athletes' effectiveness as a basis of team tactical training in women epee fencing

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Abstract
Introduction. The work studied the indicators of athletes' effectiveness in women epee fencing and the opportunity of their implementation into tactical training. According to the current researches, tactical training in team fencing is not substantiated. Aim of Study. This study aimed to compare the indicators of athletes' effectiveness of the world's top-8 women epee fencers during the season 2015-2016 in individual and team competitions and to substantiate the possibility of their use in tactical training. Material and Methods. We have recruited 8 coaches in fencing. They had to rank the components of tactical training (directions, means, methods, control tests, indicators of athletes' effectiveness). Then we analyzed the protocols and video recordings of top-8 epee fencers during the season 2015--2016 (321 bouts in individual and 207 – in team events). To estimate their effectiveness in individual and team events we used several indicators (total number of bouts, the number of won bouts, defeats, draws, and their pattern). Results. Despite the indicators of the athletes' effectiveness are high in both individual and team competitions, the ratio between them is different. Six out of eight athletes showed higher effectiveness in individual events. The difference between those indicators in individual and team performances ranged from 10.27% to 22.12%. Only two athletes performed more successfully in team matches. The difference between the indicators of their effectiveness was 7.80 and 7.05%, respectively, in favor of team competitions. Conclusions. According to the indicators of athletes' effectiveness, tactical training should be based on the use of the role models of athletes. Each role model illustrates the ability to realize athletes' potential in an individual and team standings. The role models are the following: "universal fighters", "individual fighters", "team fighters", "individual fighters with team potential".

KEYWORDS: training, preparedness, competition, team, tactical skills.

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Introduction

Exacerbation of competition in the international arena, changes in competition rules, the increase of the popularity of various tournaments in the sports season and the prestige of winning medals at the Olympic Games and World Championships, the emergence of material incentives encourage coaches to seek new training approaches [1, 4, 5, 23]. According to fundamental sources [20], the specificity of the sport is an important factor that determines the structure of the athlete's training.

The peculiarity of fencing is that, at competitions of the highest level, athletes perform not only in the individual but also in the team events. According to the current FIE (International Fencing Federation) qualification requirements, at the Games of the XXXII Olympiad in Tokyo, 12 sets of medals will be drawn – 6 in individual and team competitions. In comparison, at the previous Olympics, the number of medal sets was 10 [10]. Thus, the effort of coaches and athletes is largely focused not only on preparing to win a medal in individual competitions, but also on preparing the team during the season.

Tactical training of the team is one of the most essential parts of this process [2, 3, 6, 8, 22]. The practical experience illustrates that tactical training for individual and team competitions has some differences [29]. First of all, it is connected with the competition rules and formulas for individual and team matches. The formulas of competitions are similar for three weapons – epee, foil, and saber. The individual competition consists of two rounds: preliminary round and direct elimination. In the preliminary round, athletes are divided into groups and compete inside them. Each bout lasts 3 minutes or until the score of 5 points. In direct elimination athletes with higher ranking compete against athletes with a lower ranking. In foil and epee competitions each bout consists of 3 periods of 3 minutes and until the score of 15 points. In saber fencing, the bout consists of 2 periods until 15 points (the time doesn't matter because the dynamics of performance is very high). If an athlete wins a bout in direct elimination, he or she moves on to the next round of the competition. If he or she fails, he or she finishes the tournament.

In team competitions, there is only a direct elimination round. The couples of rival-teams are composed according to the International Team Ranking. The team consists of three participants (and one reserve participant) and should win a match against the other team to move to the next round. Contrary to the individual tournament, after one failure (when defeated in one match) the team continues the tournament and competes in other matches. A team match is a kind of relay – it consists of 9 individual bouts (3 participants of one team should compete against 3 athletes from another team) until 45 points. In foil and epee, each bout lasts 3 minutes until 5 touches. In saber, there is no time limit. In some cases, the athlete is allowed to score more hits in the personal bout (for example, if the previous team member didn't score 5 points). That is why the result of the team depends on the efficiency of each team member [4, 7, 13, 15, 16].

That is why the main difference between tactical training for individual and team bouts is the formation of a strategy for the whole competition and tactics for particular bouts (in preliminary round or direct elimination). In individual competitions, the athlete tries to win as many bouts as possible because the amount of victories influences his or her ranking in the next round – direct elimination. The pattern of scored and received hits in each bout is important but the amount of victories is more essential. In direct elimination, the array of scored and received hits doesn't matter (the winner is an athlete who scored more during 3 periods of 3 minutes or is the first who scored 15 hits). The athlete tries to win the bout, spending less energy. If the situation is favorable and the athlete confidently maintains the advantage during the bout (for example, with the weaker opponent), he or she can try to perform various technical and tactical actions to test their reliability and effectiveness. It is important not to spend too much energy, because it will be needed in the next bouts. In team matches the strategy is different. As the match is a kind of relay, it is important to use the most appropriate tactical scheme and to arrange the team members so that the last bout is conducted by the strongest and most reliable, also in a psychological context, athlete (leader). If the team lags before the last match, the leader should do everything possible to eliminate the difference and win. The other participants should do their best to support him to provide the advantage to the whole team. To do this, in each bout, they can not only strive to win but also to receive fewer hits from the rival. In some cases, a draw is also a positive contribution to the team result.

There are also some differences in tactics depending on the kind of weapon. In epee and foil the density of the bout is lower, so athletes need to distribute their effort properly for the whole match. In saber, the dynamism of the bout is higher, so athletes need to react faster to the actions of the opponent. Fast decision-making is essential for all weapons, but in saber – more.

The differences in refereeing matches and scoring in each weapon also reflects the choice of tactics. In foil, the athlete may hit only the torso, neck, groin, and back. In saber touches beneath the waist do not count (the mask and hands are also affected surface). In epee, when athletes strike each other simultaneously, they both get a point. In foil and saber, if the athletes strike each other at the same time, the referee will use the "right of way" rule, awarding the point to the competitor who began the attack first (but there may be exceptions according to the competition rules). That is why each technical action should be prepared carefully. Athletes use deceptive movements and masking actions to hide their real intentions.

Given this, the choice of tactics for individual bout differs from team matches. In individual competition this choice is mainly based on the athlete's tactical style, while in team bouts – also on the general situation during team match [17, 21, 25, 26]. That is why setting tactical tasks for a particular bout in individual and team competitions should also be different.

In this context, the peculiarities of the participants' interaction in team fencing events could be compared with sports games, where the development of technical and tactical game schemes is based on the use of each player's advantages or compensation of his or her weaknesses. This approach allows for achieving high results at competitions of different levels. Besides, it is important to take into account different characteristics of each athlete (physical abilities, technical and tactical skills, moral and intellectual qualities, authority and position in the team) and the abilities of the whole team (its national or international ranking, experience, tasks for a season, etc.) [18, 19, 22].

According to these issues, a team structure is formed (a kind of special hierarchy of relations between team members during the competition), where each member has a certain role model and status. Thus, training tasks in sports games aim at team unity and collaboration, that is why special interactions between individual players, their groups, and the whole team should be formed [17, 18, 19, 22]. In typical sports games, the athlete mainly acts under a certain game position (for example, forward, halfback, goalkeeper) during the match or season, while in fencing each of the team members might change his or her role according to the team strategy in particular competition [26, 27, 28].

Analysis of the competitive performance in fencing shows that the strongest and the most experienced athlete is not always successful in team competitions [6]. Instead, a mid-level fencer who is not usually successful in individual competitions could demonstrate leadership qualities in team events and effectively fight against various opponents [27, 28].

However, the analysis of scientific papers indicates that tactical training for team events in fencing is not properly substantiated. The majority of the researches is devoted either to the criteria for selecting athletes to the team based on the analysis of competitive performance or to the improvement of athletes' tactical skills for individual competitions [2, 4, 27, 28]. Moreover, the emphasis is made on studying and improving the most effective technical and tactical actions that could be used against particular opponents [7, 8, 9, 15]. At the same time, the attention is paid only to the performance in individual events. The main indicators are the amount of various technical and tactical actions, their effectiveness against different opponents, cinematic characteristics of technics (speed, power, pace, accuracy, etc.) [3, 4, 9, 13, 14]. In our opinion, the comparison of fencers' performance in individual and team competitions is the basis for improving tactical training and one of the areas that require more detailed study. The urgency of the study is also connected with the growing prestige of team competitions (the Olympic Games, World and European Championships, World Cup Events) and recent changes in competition rules.

Aim of Study

The purpose of the research was to compare the indicators of athletes' effectiveness of the world's top-8 women epee fencers during the season 2015-2016 in individual and team competitions and to substantiate the possibility of their use in tactical training.

Material and Methods

Our research included a few stages. Theoretical analysis and generalization were used during work with literary sources on the identification of the main problems of tactical training in fencing.

The next step included an expert assessment devoted to the issues of tactical training (February–August 2019). The experts (n = 8) were well educated (4 among them held Ph.D. diplomas) and experienced – 2 coaches of the national teams (one of the Ukrainian national team, one of the USA national team), 2 world category referees, and 2 athletes – national team's members. On average, experts had almost 15 years of experience in training fencers of different ages.

The questionnaires were administered to the experts in two different ways. Five questionnaires were administered in a paper form and filled under the supervision of the researcher. The other three questionnaires were distributed by e-mail. Each expert was asked to rank the components of tactical training in each section. The number of components in sections ranged from 5 to 10. Rank 1 was always considered the most significant. The highest rank indicated the least important component (eg. in section with 9 components, rank 9 was the least important). The total questionnaire included 6 sections concerning different aspects of tactical training. The experts' answers to the first 5 sections of the questionnaire were deeply analyzed in our previous paper [29]. The results of this article are based on expert's answers to Section 6: Team tactical training (Appendix). That section consisted of 3 questions. Experts were asked to comment on their answers or to offer their own.

To confirm the accuracy of the answers, the concordance coefficient was determined (W). The statistical significance of the concordance coefficient was verified using the

χ^2 criterion (Pearson's chi-squared test). According to Shiyan, Edinak, Petryshyn [24], the critical value of the concordance coefficient was defined as W = 0.5. Therefore, at $0.69 > W \geq 0.5$, the agreement of experts' opinions was evaluated as average, at $W \geq 0.7$ as high (strong), and at $W > 0.5$ as low (weak).

We discovered that 100% of experts insisted on the differentiation of tactical training for individual and team events. Among the indicators of competition performance which should be taken into account when preparing for team events, the most essential is the number of wins, defeats, and draws (average rank 1.48; W = 0.8, $p < 0.05$). In addition to this, 50% of experts explained that in team matches the victory of an athlete in a personal duel does not always guarantee a team victory. They added that the desire to get fewer points from the opponent and to score as much as possible is more important. Therefore, in some situations, a draw in a personal duel has a positive effect on the team match. That is why one of the most important tasks in team tactical training is a proper task-setting separately for one duel or team match, round of competition (preliminary or direct stage), and season (the average ranks of the tasks were 2.12; W = 0.79, $p < 0.05$). 37.5% of experts added that there should be some sets of tasks – separately for each team member according to their experience and abilities and for the whole team. In addition, 37.5% of experts offered to take into account the additional indicators of competition performance such as the number of bouts in which the athletes participated during the season. This information is essential to estimate the athletes' effectiveness and their contribution to the team's achievements.

The next step of the research was a pedagogical observation (November 2019 – April 2020). We analyzed the protocols and video recordings of six Ukrainian national team members (Y. Sh., A. P., K. P., A. J.-F. B., A. I., O. K.) during the season 2014-2015. It revealed that the athletes' effectiveness in individual and team events was different [6]. Their effectiveness was estimated by the number of bouts in individual and team competitions during the season, the ratio between won bouts, defeat bouts, and draws. It was found that some athletes who achieved high results in individual competitions (World and European Championships) were not successful in team events. We have suggested that this situation may be typical not only for Ukrainian athletes but also for top fencers. The next stage of the research aimed to confirm or refute that assumption.

We analyzed the protocols and video recordings of competitions in epee fencing during the season 2015--2016 (321 bouts in individual and 207 – in team events). Our attention was focused on the performance of the eight top athletes according to the FIE Ranking (International Fencing Federation). Among them: R. F. (Italy), A. N. (Italy), E. S. (Hungary), T. L. (Russian Federation), A. S. (Republic of Korea), Y. S. (People's Republic of China), W. X. (People's Republic of China), A. P. (Romania).

Evaluation of athletes' effectiveness in individual and team competitions differed slightly. During the 2015--2016 season, the athletes participated in 14 individual tournaments: Grand Prix series, World Cup Events, continental competitions (European and Asian Championships), the World Championships, and the Games of the XXXI Olympiad. According to the FIE rules, the 16 best athletes in the world rankings do not participate in the preliminary (qualifying) round of individual competitions. They start their performances with the 1/32 stage of the competition in the round of direct elimination (automatically get to the list of "top-64"), so all bouts are held to 15 points. According to the specifics of individual competitions and experts' opinions, we took into account the ratio between the number of won matches and the total number of bouts.

To determine the indicators of athletes' effectiveness in team events, we analyzed their performance at three main tournaments of the 2015-2016 season – the World Championship in Moscow (Russian Federation), European Championship (Torun, Poland), the Games of the XXXI Olympiad (Rio de Janeiro, Brazil). We analyzed the ratios between the numbers of victories (won bouts), defeats, and draws and the total number of bouts in all matches. We calculated a ratio between the number of victories and the total number of bouts held in individual competition (Victory/Total, individual); a ratio between the number of victories and the total amount of bouts held in team competition (Victory/Total, team); a ratio between the number of defeats and the total amount of bouts held in team competition (Defeat/Total, team); a ratio between the number of draws and the total amount of bouts held in team competition (Draw/Total, team). Such calculations were made personally for each athlete.

Statistical processing of the data was carried out using the standard Statistica 7.0 program. To compare the experts' answers on a questionnaire we used the average rank (arithmetic mean of all ranks assigned to a particular position of tactical training issues in each question). To confirm the accuracy of their answers, the concordance coefficient was determined (W). The statistical significance of the concordance coefficient was verified using the χ^2 criterion (Pearson's chi-squared test). The level of significance was set at $p < 0.05$. The indicators of athletes' effectiveness were calculated using the Microsoft Excel program (version 2016).

Results

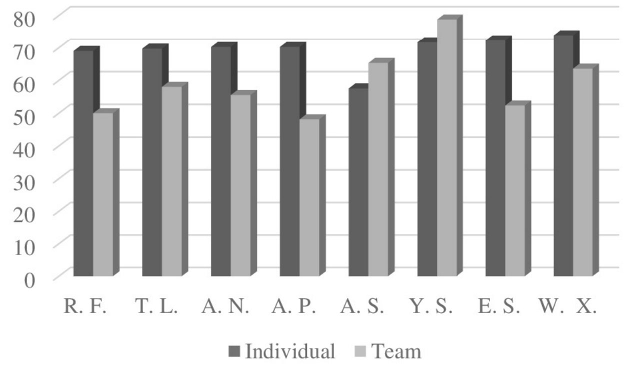
It was revealed that the effectiveness of the top-8 women epee fencers during the 2015-2016 season in individual events is high – from 57.58 to 73.91% (Table 1, Figure 1). In team competitions, the best pattern of the number of defeats and draws was performed by T. L. (12.90% defeats and 29.03% draws), Y. S. (9.09 and 12.12%, respectively), W. X. (12.12 and 24.24%, respectively). Other athletes failed to minimize the number of defeats in individual duals during team matches (Table 1, Figure 2).

Table 1. Effectiveness of the top-8 women epee fencers in team competitions in the 2015-2016 season (n = 8)

No.	Athlete	The indicators of athlete's effectiveness			
		Individual events	Team events		
		Victory/ Total (%)	Victory/ Total (%)	Defeat/ Total (%)	Draw/ Total (%)
1	R. F.	69.05	50.00	44.44	5.56
2	T. L.	69.77	58.06	12.90	29.03
3	A. N.	70.27	55.56	33.33	11.11
4	A. P.	70.27	48.15	29.63	22.22
5	A. S.	57.58	65.38	26.92	7.69
6	Y. S.	71.74	78.79	9.09	12.12
7	E. S.	72.34	52.38	38.10	9.52
8	W. X.	73.91	63.64	12.12	24.24

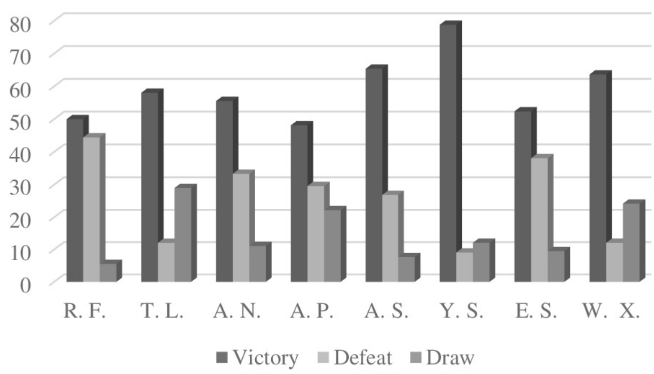
Although the indicators of the athletes' effectiveness are high in both individual and team competitions, their array is different. Six out of eight athletes showed higher effectiveness in individual events (R. F., T. L., A. N., A. P., E. S., W. X.). The difference between studied indicators in individual and team performances ranged from 10.27% to 22.12%. At the same time, it was the highest for the following athletes: R. F., T. L., W. X. (19.05-22.12%). In comparison, only two athletes – A. S. and Y. S. – performed more successfully in team matches. The difference between the indicators of their effectiveness was 7.80 and 7.05%, respectively, in favor of team competitions.

The best pattern between victories, defeats, and draws in team events was revealed for Y. S. (78.79%; 9.09%;



Note: The indicators of athlete's effectiveness: individual – a ratio between the number of victories and total amount of bouts held in individual competition (%); team – a ratio between the number of victories and total amount of bouts held in team competition (%)

Figure 1. The comparison of the top-8 women epee fencers' effectiveness in individual and team competitions in the 2015-2016 season (n = 8)

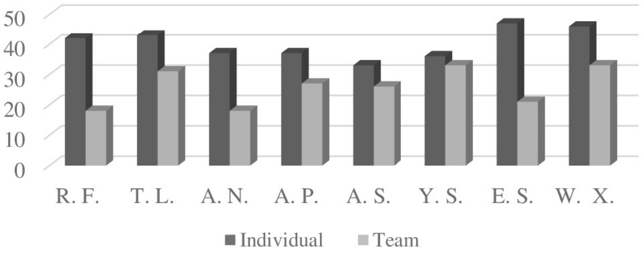


Note: The indicators of athlete's effectiveness: victory – a ratio between the number of victories and total amount of bouts held in team competition (%); defeat – a ratio between the number of defeat bouts and total amount of bouts held in team competition (%); draw – a ratio between the number of draws and total amount of bouts held in team competition (%)

Figure 2. The comparison of the top-8 women epee fencers' effectiveness in team competitions in the 2015-2016 season (n = 8)

12.12% respectively) and W. X. (63.64%; 12.12%; 24.24% respectively). The worst pattern of those indicators was demonstrated by R. F. (won bouts – 50.00%; defeats – 44.44%; draws – 5.56%), A. N. (55.56%; 33.33%; 11.11% respectively), and E. S. (52.38%; 38.10%; 9.52% respectively).

The difference in the number of individual bouts was connected with the specifics of athletes' performance in individual and team competitions. Some team members may not perform at all stages of the competition or compete only against particular opponents following the team's strategy. At the same time, a great amount of bouts in team events confirms that the athlete is effective and can influence positively the result of team matches. We analyzed the protocols of team competitions and discovered that the fewer amount of team bouts was caused by the following reasons: 1) the athlete performed in team match unsuccessfully and the coaching staff made a replacement (a reserve athlete continued further bouts and matches instead of an unsuccessful colleague); 2) an athlete didn't participate in the team tournament, but she took part in individual event a day before; 3) the team was defeated at earlier stages of the tournament (Figure 3).



Note: The number of bouts is represented as absolute value. Individual – the total number of bouts performed by each athlete in individual events in the 2015-2016 season; team – the total number of bouts performed by each athlete in team events in the 2015-2016 season

Figure 3. The number of bouts performed by the top-8 women epee fencers in individual and team competitions in the 2015-2016 season (n=8)

As shown in Figure 3, some athletes participated in a great number of bouts in individual events, but the amount of performed bouts was low in the team competition. This situation is typical for R. F. (42 and 18 bouts respectively), A. N. (37 and 18 bouts respectively), E. S. (47 and 21 bouts respectively).

Discussion

In most scientific papers on fencing, the main subjects of the research are the ways to improve various aspects of athletes' training and to determine the prerequisites for their successful implementation during individual competitions [12, 15, 16, 21]. At the same time, the specifics of athletes' actions in team events and preparation for them are mentioned fragmentally [6, 7, 27, 28]. As for team competitions, the subject of research is usually connected with athletes' selections taking into account different indicators. These indicators include the level of athletes' preparedness (physical abilities, technical and tactical skills, psychological qualities), the position in the national or international ranking, the achievements in different competitions, and sports experience. Moreover, the success in team competitions in fencing depends both on the efficiency and effectiveness of athletes. In sports literature, the concepts of efficiency and effectiveness have different interpretations. The effectiveness is often considered as the performance of a certain result – demonstrating the best time on a distance in swimming, scoring a goal in football, lifting a certain weight in powerlifting, getting high points in rhythmic gymnastics, winning a medal, etc. [20, 21]. Instead, efficiency is characterized by closeness to the sample, which is chosen to have the most rational version of the technique, determined based on biomechanical, physiological, psychological, aesthetic considerations [20]. Some authors insist that effectiveness might be considered as a component of efficiency [7, 8, 27]. For example, basketball, volleyball, and football experts analyze player's efficiency using calculation of the general amount of technical and tactical actions, the amount of successful and erroneously performed actions during the game, correlation between offensive and attacking actions [18, 22, 23]. In comparison, in fencing effectiveness of technical and tactical actions is measured by matching the number of performed actions and actions that affected the opponent and allowed to score a hit [7, 8, 17, 21].

As for tactical training, it is usually devoted to the improvement of tactical skills in combination with technical, decision-making, and the choice of action during individual duels [21, 25, 26]. The most fundamental research devoted to tactical skills in fencing during the last 10 years was made by Ryzhkova [21]. The author also used an expert assessment for the determination of the most essential components of tactical preparedness and developed several technologies for the formation and improvement of athletes' tactical skills at different stages of long-term training [21]. The effectiveness of such technologies was revealed in pedagogical experiments. In our opinion, this research is very useful for fencers, but it doesn't take into account the specifics of team training and aims only to successful participation in individual events.

At the same time, a great number of issues of tactical training remain undiscovered. It concerns the formation of team strategy for the season, the use of tactical schemes in team matches against different opponents, the sequence of team-members' performance during a team match, goal setting for the whole team competition, team match, individual duel or its fragment.

From this point of view, tactical training in fencing is slightly similar to ball games (football, basketball, volleyball). In such sports, each team member has special duties during the match according to his or her position [5, 18, 19, 22, 23]. Practical experience in fencing indicates that team members also have special duties, but fencer's position during team events may differ (in one team match he or she may perform as a leader, in other matches – as an assistant of the leader). The choice of position for a particular match depends on many factors: the level of preparedness of team members, the composition of the rival team, stage and level of competition. Equally important is the psychological aspect – usually, the position of a leader is taken by reliable athletes who are able to withstand psychological pressure in case of backlog and are willing to bear great responsibility [27, 28]. Practice shows that even elite athletes with a high international ranking are not always ready to act as a leader in team competitions.

Unfortunately, the positions and duties of team members in fencing are not described in scientific papers at all. There are some classifications of individual competition styles based on the choice of technical and tactical actions, psychological abilities (motor reaction time), or affiliation to the traditional schools (Italian, French, Hungarian, etc.) [2, 7, 8, 12, 17]. However, there are still no classifications of tactical styles that are used in team competitions. In our opinion, this knowledge is essential for the formation of team strategy during the season, tactical schemes for different stages of competitions (preliminary stage or direct elimination), and matches with various opponents. From this point of view, analysis of the athlete's effectiveness in team events in comparison with individual tournaments is actual.

The results of our study indicated that elite women epee fencers realize their potential in different ways depending on the type of the event (individual or team standing). The 2015-2016 season was a pre-Olympic period, that is why each of the top-8 fencers solved different tasks in competitions. The tasks could be connected with their place in the world rankings at the time of the next tournament and the prospects of individual or team Olympic qualification. At the same time, the athletes had to perform as successfully as possible in almost every tournament, as the points gained in it could significantly affect not only the place of a particular athlete in the personal world rankings but also the rotation of the national team.

The success of some athletes in individual competitions and their failures in team events could be attributed to the following reasons. We can assume that by the decision of the coaching staff of R. F. and A. N. were focused on individual qualification for the 2016 Olympics. That is why their performance in team matches was used to implement other tactical tasks (studying potential rivals, finding the optimal manner of fighting with different opponents, hiding their preparedness, etc.). From the opposite point of view, the inability of their national team to qualify for the Games of the XXXI Olympiad may be caused by errors in the distribution of functional responsibilities between team members in matches with various teams.

The analysis of athletes' effectiveness in the 2015-2016 season (the comparison between the number of won bouts, defeats, and draws in team events with their performance in the individual competition) allowed us to determine the role models for team members depending on the success of their performance in individual and team competitions. These roles are the following:

1. "Universal fighters". Such fencers are highly effective both in individual and team competitions (in our research the difference between the indicators of their effectiveness ranged from 7.05 to 10.27%). In our research, such role models were typical for Y. S. and W. X. Both athletes have won medals in individual and team competitions at all greatest tournaments of the season (the Games of the XXXI Olympiad, World and Asian Championships), and the difference between the indicators of their effectiveness in individual and team events is small. They are able to win medals and to make a significant contribution to the team result. "Universal fighters" are essential in the Olympic qualification, as the inclusion of such athletes in the national team guarantees a high chance of winning both personal and team Olympic licenses and medals.

   In our opinion, one of the main tasks of tactical training for "universal fighters" is to distribute their effort and to maintain their physical conditions during the individual tournament and not to exhaust all potential prematurely. From a tactical point of view, in unimportant matches during team competition (for example, against a weak opponent), these athletes may not participate in order to save their opportunities for the bouts with more experienced rivals. Preparing for the highest level competitions, such athletes must face complex tactical tasks – providing an advantage for the team, leveling a large difference in the score (when the rival team is leading during the match), using the arsenal of technical and tactical actions as wide as possible, search for untypical combinations of actions for which the opponents are not ready.

2. “Individual fighters”. These athletes purposefully put more effort into successful performance in individual competitions and consciously neglect to participate or to succeed in team competitions. In our research, such role models were typical for R. F., A. N., E. S., and A. P. These athletes show much higher rates of individual performance in individual competitions, and in the team competitions, the number of defeats exceeds the number of draws. From a tactical point of view, their performance in team competitions is associated with certain risks, even if they stepped on the medal podium the day before in the individual tournament. The inclusion of such fencers in the national team provides a great chance to win medals in the individual competition, but it does not guarantee success in a team tournament. Their effectiveness in the Olympic team qualification depends on different factors.

   From a tactical point of view, such athletes should prepare exclusively for individual competitions. In team events, the best for them is to support the leader. Tactical training should focus on improving tactical skills, tactical schemes, and technical actions that will effectively beat experienced athletes. In comparison with “universal fighters”, the number of such schemes and actions may be lower.

3. “Team fighters”. Such fencers achieve high results in team competitions, but in individual standings, their performance is less successful. In our research such a role model was typical for A. S. Unlike “individual fighters”, these athletes are able to maximize their potential in team matches. Whatever their performance is in the individual tournament, their contribution to the team’s result is perhaps the largest among other team members. Practice shows that based on the tactical point of view, these athletes are not always included in the national team performing in the individual events, but they are involved when participating in a team tournament. Therefore, according to the decision of the coaching staff, two different teams may be declared for competitions (the first one – to perform in the individual event, the second one – to compete in a team).

   According to the specifics of the competition rules (each team bout lasts for 3 minutes and is more intensive than in individual events), the task of tactical training of these athletes is to develop the ability to score the maximum number of points within 3 minutes. The arsenal of technical and tactical actions may not be wide, but they should be reliable and effective against various opponents. Such athletes need to train as team leaders with the greatest responsibility.

We can also mention the role model of “individual fighters with team potential”. They usually demonstrate high results in individual competitions, but occasionally or by the decision of the coaching staff can direct their efforts to successful team performance (for example the need for Olympic team qualification). In our research, such a role model was typical for W. X. and T. L. The difference between the indicators of individual performance of these athletes in individual and team competitions is less pronounced than in the previous group. At the same time, the number of draws is higher than the number of defeats. As rule, such fencers may achieve high results in individual events. However, if they are not successful during the season, the coaching staff may persuade them to neglect individual events and to concentrate on team competitions.

We didn’t investigate the psychological aspects of obtained results, therefore it is a limitation of this study, and at the same time the prospective for further work. However, we can assume that the difference between athletes’ effectiveness in individual and team events may depend on psychological variables. On the one hand, in individual competition athlete should take responsibility only for himself (herself). That is why he or she tries to do everything possible to succeed. In team events the situation is different. Some athletes feel the support of other team members, so they act more confidently in individual fights, even when the rival is much more experienced. It is important for them not to let other athletes down and do everything possible to get a team victory. Even if such athletes perform unsuccessfully in the individual tournament, they mobilize and perform excellently in team bouts. Even middle-class athletes can be so eager to do everything possible for the team that they beat the titled rivals with a big advantage (although the day before, in the individual tournament, they could have lost against these rivals with a big gap). Instead, there is a category of athletes who do not withstand psychological pressure, especially if it is necessary to take responsibility for the team. They can’t end the team match (the last and the most important bout) because they are very insecure out of excitement. Therefore, not always a strong athlete acts as a leader.

Conclusions

Based on our results there are four models of fencers: “universal fighters”, “individual fighters”, “team fighters”, and "individual fighters with team potential". In our opinion, this classification should be the basis for developing a strategy to prepare the team for competition during the Olympic cycle and season. Moreover, tactical training of athletes for individual and team competitions should differ depending on their current performance. The results of our research could be useful for fencing coaches, regardless of weapon type.

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Conflicts of Interest
The authors declare no conflict of interest.

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Appendix

Dear expert!
We ask you to express your opinion regarding the tactical training of elite athletes in your kind of sport (Olympic combat sports).

Full name: ....; age: ....;
kind of sport: ....; qualification: ....;
coaching category: ....;
scientific degree: ....;
experience as a coach and/or teacher: ....;
place of work: ....

Section 6*. TEAM TACTICAL TRAINING

Indicate the importance of differentiation tactical training in individual and team competitions.

Yes, tactical training for individual tournaments should differ from tactical training for team events	
No, tactical training for individual and team events may be similar	

Comment your answer ....
....
....

Indicate the indexes of competition performance which should be taken into account when preparing for team events, ranging from 1 (most significant index) to 7 (least significant index).

No.	Indexes of competition performance	Rank
1.	The layout of wins, defeats and draws	
2.	The result in tournament (winning a medal or particular place)	
3.	The amount of effective actions:	
	– attacks	
	– defensive actions	
	– actions in different affected zones (depending on weapon)	
	– actions made in different zones of the fencing piste (depending on weapon)	
	Your offer:	

Comment your answer ....
....
....

Indicate the importance of tasks in team tactical training ranging from 1 (most significant task) to 8 (least significant task).

No.	Tasks	Rank
1.	A proper task-setting separately for one duel or team match	
2.	A proper task-setting separately for round of competition (preliminary or direct stage) or season	
3.	The choice of tactical style of each team-member	
4.	The analysis of competition performance of potential rivals	
5.	The formation of tactical style for the whole team	
6.	Determining the optimal sequence of participants' performance during the team match	
7.	Preparation of team members for performances in the most responsible bouts of the match	
	Your offer:	

Comment your answer ....
....
....

Date ....   *Signature* ....

Thank you for your help!

* Sections 1-5 are available in our previous article [Zadorozhna O, Briskin Yu, Pityn M, Perederiy A, Neroda N. Tactical training of elite athletes in Olympic combat sports: practice and experience. Trends Sport Sci. 2020;27(2):71-85. doi:10.23829/TSS.2020.27.2-4].

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A combination of ballistic exercises with slow and fast stretch-shortening cycle induces post-activation performance enhancement

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Abstract
Introduction. **The stretch-shortening cycle (SSC) ability of a muscle is responsible for sprinting and changing direction during sports activity. Sprinting involves more fast SSC ability while a change of direction (COD) requires both fast and slow SSC. Post-activation performance enhancement (PAPE) is an acute enhancement of muscular performance due to previous muscular contraction. Heavy resistance exercises and plyometric exercises are commonly used PAPE method, utilizing either slow or fast SSC activity for inducing PAPE.** Aim of Study. **This study aimed to examine the effect of a combination of ballistic exercises (BE) with slow and fast SSC on sprint and COD ability.** Material and Methods. **In a randomized crossover manner, 12 male university basketball players (age 21 ± 1.2 years; height 170 ± 8 cm; body mass 66.8 ± 7 kg; fat percentage (%) 10.2 ± 2.4) performed 3 × 5 repetitions of a combination of box jump and immediate drop jump (BDJ) or walking control after a standard warm-up protocol. A baseline measurement was recorded 1 minute after warm-up and post-measurement after 3 minutes of interventions.** Results. **Significant large improvement in COD performance was observed after BDJ compared to baseline ($p < 0.001$, $d = 0.982$) and controlled conditions (interaction effect; $p = 0.006$, partial $\eta^2 = 0.518$). While, no improvement was found in 15 m sprint performance with baseline ($p = 0.282$, $d = 0.285$) or controlled conditions (interaction effect; $p = 0.649$, partial $\eta^2 = 0.020$).** Conclusions. **The results of the study suggest that warm-up followed by a BDJ protocol induces PAPE effect and improves COD performance.**

KEYWORDS: modified agility T-test, 15 m sprint, BDJ, box jump, drop jump, SSC.

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Introduction

Basketball is a sport that involves many diverse activities like acceleration, deceleration, and COD during the game in response to an opposing player or ball movement [38]. It requires players to be exceptional in multidirectional movements such as forward, backward, and lateral sprints [35]. Modified agility T-test (MAT) is a modification of the T-test and is a reliable test for assessing change of direction ability of basketball players, as it includes forward, lateral, and backward movements [35]. Although T-test is a widely used agility test, it does not entirely replicate movement patterns involved in field or court sports. The total sprinting distance covered in T-test is approximately 40 m while the mean distance of sprints during field or court sports is between 10 and 20 m [2]. MAT involves a total distance of 20 m and thus replicates the requirements of field or court sports [35].
Warm-ups are performed before sports or activity to attain optimal performance [27] and prevent injuries by increasing muscle temperature, nerve conductivity, metabolic reactions [4], blood flow, elevated oxygen consumption, and PAPE [17]. PAPE is an acute

enhancement of muscle performance measured through maximal strength, power, and speed following a conditioning activity/contraction [34] performed intending to maximize movement velocity [11]. PAPE based warm-ups have shown to produce a small increase in jump performance and a large improvement in sprint performance compared with control or other warm-up activities [16].

Previous studies have suggested different forms of heavy resistance exercise to induce PAPE in athletes, which may not be feasible due to practical and logistical considerations [23, 29]. Maloney et al. [24] suggested that BE if implemented correctly can be an alternative to high resistance exercises since maximal motor unit recruitment can also be achieved with these exercises. BE involves either a jumping action where the body leaves the ground or a throwing action where the projectile leaves the hand. Box jump and drop jump are both BE, with slow and fast SSC involvement due to their contraction time before the jump [36]. Combining different BE with fast and slow SSC characteristics may benefit activating the muscle fibers in different ways, due to different visco-elastic properties possessed by fast and slow-twitch muscle fibers [6].

The effect of a combination of slow and fast SSC activity as in BDJ on the PAPE effect has not been studied. Box jump involves a countermovement jump onto the box. While a drop jump is attempted by dropping from the box and attempting an immediate vertical jump for maximum height after landing on the ground. Unlike other PAPE methods, whose practical implementation may be limited due to cost, or safety concerns, and may not be afforded by teams or athletes with a limited budget. In such cases, BDJ may be beneficial due to its cost-effectiveness feature requiring only a box to perform the protocol. This study investigates the acute effect of a BDJ protocol after a warm-up on MAT and 15 m linear sprint test performance.

Aim of Study

The aim of this study was to find the effect of a combination of fast and slow SSC on acute performance enhancement of (a) 15 m linear sprint and (b) modified agility T-test (change of direction ability).

Material and Methods

Subjects

A total of 18 subjects agreed to participate in the study and were present during the familiarization and anthropometric measurements. 12 subjects (Mean ± SD; age 21 ± 1.2 years; height 170 ± 8 cm; body mass 66.8 ± 7 kg; fat percentage (%) 10.2 ± 2.4) completed the study (Table 1). The study was conducted during the off-season after completion of the university games. Inclusion criteria for the study were the absence of major lower limb injury in the past 6 months, any other recent injury, or neuromuscular disorder which could potentially limit performing sprints and jumps. Subjects reported participation in plyometric training in the past. After the explanation of the procedures, players signed the informed consent form, confirming their voluntary participation in the study. This study was approved by the Departmental Research Committee of the Institute and conducted following the Declaration of Helsinki.

Table 1. Subject characteristics

Participants (n = 12)	Mean ± SD	Range
Age (years)	21 ± 1.2	19-23
Height (m)	1.7 ± 0.8	1.6-1.9
Body Mass (kg)	66.8 ± 7	54.3-75.3
Fat Percentage (%)	10.2 ± 2.4	7.4-14.7
BMI (kg/m^2)	22.1 ± 1.4	19.5-23.9

Experimental approach to the problem

A within-subject randomized crossover design with a controlled condition was used to investigate the effect of BDJ protocol after a warm-up on MAT and 15 m linear sprint performance. The participants were evaluated on 2 separate days in a randomized crossover manner with a minimum interval of 48 hours between sessions to avoid carry-over effect. Both sessions were conducted in the same period of the day (11.00 to 13.00) to minimize the circadian effect on performance. Each subject followed a 10-minute warm-up protocol followed by baseline assessments. After 3 minutes of baseline assessments, subjects either performed BDJ protocol or walked for 3 minutes (Figure 1). The post-intervention assessment was done at approximately 3 minutes, as the PAPE during BE has been observed with recovery duration ranging from 1 to 3 minutes [24]. Randomization was carried out using an online randomization tool (www.randomizer.org). The assessment protocol included MAT and 15 m linear sprints in a sequential order to maintain consistency throughout assessments, and minimize any possible fatigue effect among variables. All assessments were carried out in a synthetic basketball court by the same researchers who were blind to the allocation of intervention throughout the study.

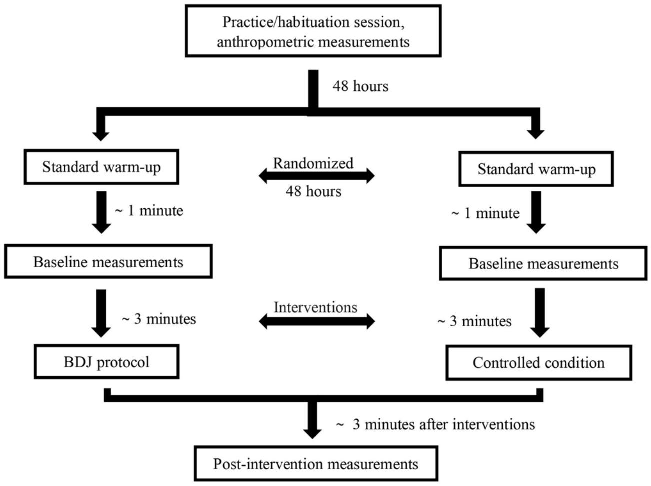

Figure 1. A schematic diagram of the design followed in the study

Procedure

One familiarization session was conducted for the participants with the BDJ and test protocols to avoid possible interferences in the results as a function of learning and coordination of movements. Players' fitness characterization by anthropometric measures was obtained the same day. Height, body mass, and body fat percentage were recorded (Table 1). The mean daily temperature during data collection was 28°C (82.4°F). The participants were asked to avoid alcohol for 24 hours, caffeine for 6 hours, food for 3 hours before the assessment, and any strenuous exercise 24 hours prior, or between the assessment days.

On the assessment day, the subjects first underwent a 10-minute warm-up, followed by baseline assessment, PAPE intervention or controlled condition, and post-intervention assessment. Warm-up started with dynamic stretching exercises in a full kinematic range for hamstrings, quadriceps, adductors, hip flexors, and soleus. It was followed by jogging, COD runs, repeated sprints, acceleration sprints, and line drill (Table 2).

BDJ protocol

A box of 0.65 m height was used for the study since a drop height of 0.65 to 0.72 m were found to have maximum jump height without the influence of leg strength [41]. BDJ was performed by jumping onto the box after a countermovement and then dropping from the box with an immediate vertical jump with minimum ground contact time (Figure 2). Subjects performed 3 sets of 5 BDJ repetitions with a rest period of 10 seconds between repetitions and 60 seconds between sets.

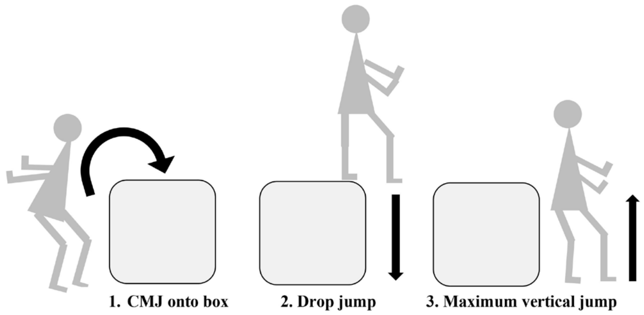

Figure 2. Diagram of BDJ exercise which includes a CMJ onto the box and an immediate drop jump

Modified agility T-test and 15 m linear sprint test

MAT was used to determine the speed with directional changes, which included forward sprinting, left and right shuffling, and backward running (Figure 3). The test was administered according to the guidelines set by Sassi et al. [35]. A pair of single beam photocell timing system (Cronox, Madrid, Spain) was placed at the start/finish line.

15 m linear sprint test was used to determine the acceleration speed and assessed using two pairs of

Table 2. The warm-up protocol followed in the study

Sl. No.	Activity with description	Duration	Repetitions	Rest interval
1	Dynamic stretching: exercises in a full kinematic range for hamstrings, quadriceps, adductors, hip flexors, and soleus	2 minutes		
2	Jogging: continuous jogging at submaximal intensity	3 minutes		
3	Shuttle runs: each shuttle run repetition consist of 3 COD runs from baseline to free throw line	2 minutes	3 × 5.8 m	15 sec
4	Acceleration sprints: sprints from the baseline up to center line	2 minutes	3 × 14 m	15 sec
5	Line drill: start from the baseline, touch every horizontal line of the court (i.e. free throw line of backcourt, center line, free throw line of frontcourt and baseline of other side), and finish on the starting baseline	1 minute	1	

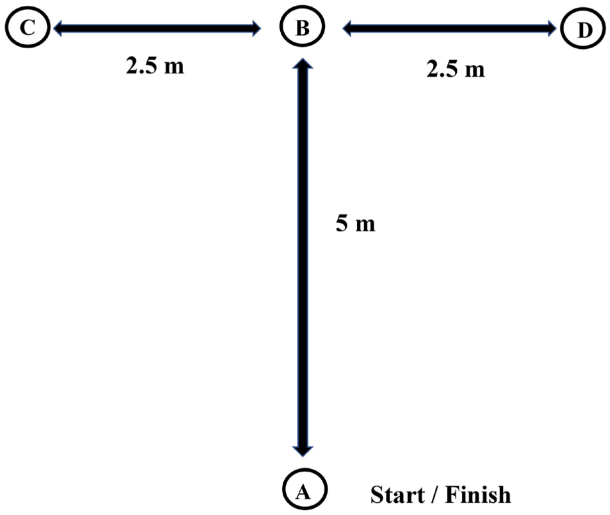

Figure 3. Modified agility T-test. The subject runs forward from A to B, then shuffles to C, then shuffles to the right to D, then shuffles back to B, before running backward to the start/finish line at A

photocell timing system (Cronox, Madrid, Spain) placed 15 m apart. In both MAT and 15 m sprint test, the photocell timing system were placed at a height of 0.6 m and subjects started 0.5 m behind the first photocell and were instructed to begin with their preferred foot forward on a line marked on the floor from a standing position. Two trials were conducted for each test with a rest period of 1 minute between each trial and test [32]. The best timing was selected for analysis.

Statistical analysis

Data were analyzed using IBM SPSS (version 20.0.0) and presented as Mean ± SD. Shapiro–Wilk test approved the normality of the data. A two-way (2 × 2) repeated measures ANOVA with time (baseline and post-intervention assessments) and interventions (BDJ and control) as within-within subject factors were used for analyses. The interaction effect between time and intervention was used for finding the effectiveness of the BDJ protocol. A paired T-test was conducted to observe differences between baseline and post-assessment. The effect size of the interaction effect was calculated using partial η^2 with 0.01 defining small, 0.06 medium, and 0.14 large effect. Cohen d were calculated for baseline and post-assessment difference with 0.20 defining small, 0.50 defining medium, and 0.80 defining large effect sizes. The level of significance for all tests was set at 0.05.

Results

Two-way repeated-measures ANOVA revealed significant interaction effect (time × intervention: $p = 0.006$, partial $\eta^2 = 0.518$) in MAT with a large effect size (Figure 6). MAT performance was also significantly higher ($p < 0.001$, $d = 0.982$) after BDJ protocol than baseline. No significant interaction effect was found in the 15 m linear sprint test (Table 3).

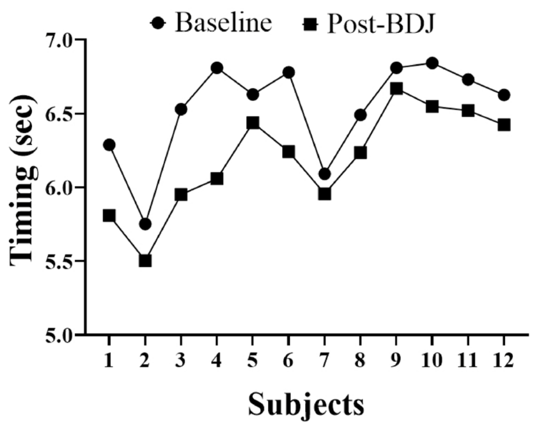

Figure 4. Graphical representation of the individual performance of MAT during baseline and post-intervention using the BDJ protocol

Table 3. Baseline and post-intervention scores of MAT and 15 m sprint of subjects during BDJ and controlled condition

	Intervention	Baseline Mean ± SD	Post-intervention Mean ± SD	P-value With baseline	E.S. (d) With baseline	P-value Interaction	E.S. (η^2) Interaction
MAT (sec)	BDJ	6.532 ± 0.335	6.197 ± 0.348	<0.001 †	0.982	0.006 ‡	0.518
	CON	6.205 ± 0.24	6.311 ± 0.307	0.267	0.384		
15 m sprint (sec)	BDJ	2.491 ± 0.075	2.508 ± 0.069	0.282	0.245	0.649	0.020
	CON	2.487 ± 0.088	2.494 ± 0.099	0.549	0.079		

Note: MAT – modified agility T-test, BDJ – box and drop jump, CON – controlled condition, E.S. – effect size, d = Cohen d, η^2 – partial eta square, † significant difference compared with baseline; ‡ significant interaction effect between BDJ and control condition

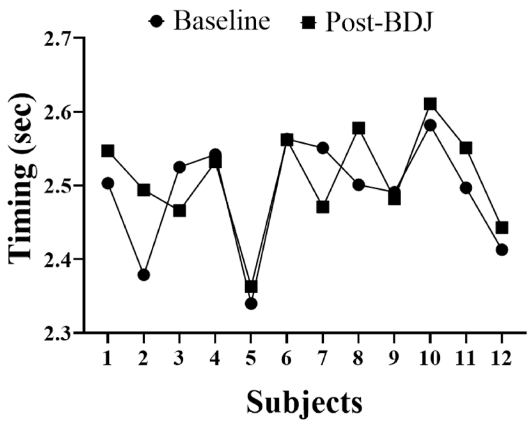

Figure 5. Graphical representation of the individual performance of the 15 m linear sprint test during baseline and post-intervention using the BDJ protocol

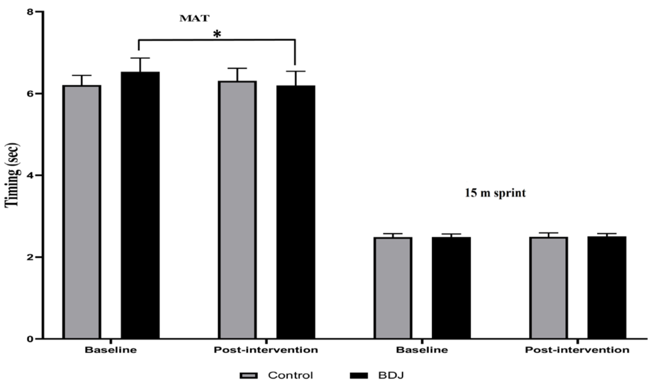

Figure 6. Mean ± SD of MAT and 15 m sprint performance

Discussion

The study aimed to find a PAPE effect through a combination of slow and fast SSC activity (BDJ) on MAT and 15 m linear sprint ability of university basketball players. The study demonstrated BDJ as an effective method of inducing PAPE during MAT compared with a controlled condition and within-condition baseline assessment. The findings suggest that performing BDJ after warm-up is highly effective in acute improvement of MAT performance as large effect sizes were observed in the interaction and within condition effect.

Different PAPE protocols have been used earlier to augment power production in athletes from varying sports, but the limitation of all those PAPE methods was the need for heavy loading using equipment, which is costly and has logistical as well as safety considerations. This led researchers to find alternative ways of inducing PAPE and overcoming those limitations. To the authors' knowledge, plyometric exercises using alternate-leg bounding [44], drop jump based on vertical or horizontal components [5, 7, 12], and a combination of ankle hops, hurdle hops, and drop jumps [20] have been studied for inducing PAPE in athletes. The above studies reported that a very heavy loading preload stimulus is not necessary for inducing PAPE. Our study supports these findings, as BDJ including 3 sets of 5 repetitions is found to be sufficient in inducing PAPE during MAT. Previous studies by Petisco et al. [32], Maloney et al. [25], and Okuno et al. [30] support our finding of BDJ inducing PAPE during MAT. These studies used external weight, ranging from 5% to 10% body mass during warm-up [25], and 50% to 90% of 1 RM back squat [30, 32] as conditioning activity which may put an unconditioned athlete at risk of getting injured. On the other hand, the use of BDJ protocol is safer than its heavy resistance counterparts such as 80% or 90% of 1 RM back squat, while also being cost-effective. As per the authors' knowledge, very few studies have been conducted on the effect of conditioning activity inducing PAPE during the change of direction ability. Lack of studies of PAPE effects on COD ability using plyometric exercises limits the authors to make other possible comparisons.

Lack of electromyography recording has been a limitation to this study, but the PAPE effect has been continuously linked with maximal activation of the muscles involved during the activity and is a key component in inducing PAPE [44]. Maloney et al. [24] suggested that the correct implementation of BE can be a substitute for high resistance exercise since BE also seeks to achieve maximal motor unit recruitment without heavy and expensive equipment. BE is characterized by jumping or throwing actions, where either the body leaves the ground or a projectile leaves the hand. In a BE, the braking phase found in traditional resistance exercise is eliminated, which increases the relative duration of positive acceleration facilitating greater muscle activation and force output [28]. The motor unit recruitment threshold is lower during a ballistic contraction than slow ramped contraction [13, 18, 45], which enables the entire motor neuron pool to be activated within a few milliseconds due to the strong excitatory drive of ballistic contraction [14]. BDJ includes two entirely different BE, a box jump, and a drop jump, which are categorized as slow and fast SSC, due to the duration of contraction time before the jump [36]. Slow-twitch and fast-twitch muscle fibers have different visco-elastic properties which allow them to benefit differently from both slow and fast SSC [6]. Tillin and Bishop [43] also proposed that greater neural excitation may be facilitated with drop jump due to its increased eccentric pre-loading components. MAT requires the use of both fast and slow SSC during multidirectional movements and changing directions. This combination of slow and fast SSC ballistic activity during BDJ could be a factor in the recruitment of different muscle fibers [6], thus potentiating both SSC qualities of muscle, and enhancing MAT performance. This improvement in the MAT performance may also be related to an acute increase of reactive strength [39] after the BDJ protocol. Reactive strength is the ability to change quickly from the eccentric phase to the concentric phase during an SSC muscle action [49]. Thus, a greater reactive strength would possibly improve the ability to perform sudden stops and to quickly accelerate from there [40], hence improving MAT performance. Also, BDJ protocol utilizes both fast and slow SSC abilities during the conditioning activity which might have helped to better utilize the SSC during the deceleration-acceleration transition of the COD movement.

Maloney et al. [24] suggested PAPE to be affected by the stiffness of the muscle-tendon unit. An increase in the stiffness at the musculotendinous unit level allows the muscle to function in a more quasi-isometric manner, increasing the potential for elastic recoil from the passive state which increases force development in the active component [31]. Thus, an increase in stiffness in the leg would improve reactive strength measures and relative force contribution of the SSC (i.e. passive tension to force production) during powerful movements due to the viscoelastic properties of the musculotendinous unit [1, 31]. Although we did not include stiffness measurement in the study, it is known that during ballistic activity, the muscle-tendon unit is required to stiffen to function effectively [31]. Plyometric training has also been effective in enhancing the extensibility of tendon during ballistic contractions and active muscle stiffness during fast stretching, improving performance during SSC activity [19].

Another finding of this study was insignificant changes in 15 m sprint performance, which is in line with previous studies [3, 8-10, 15, 21, 26, 42, 44, 46, 48]. These studies included plyometric as well as heavy resistance exercises as conditioning activity, such as double leg tuck jump, alternate leg bounding with or without weight, resisted sled sprints, power cleans, back squats with varied load and repetition. The sprint distance ranged from 5 m to 40 m and recovery duration from ~15 seconds to 16 minutes. In contrast, few studies also reported improvement in sprint performance using PAPE interventions [5, 7, 8, 22, 37, 44, 47]. The interventions included sled pulls with 75% and 150% of body mass, individualized drop jump, alternate leg bound using a weighted vest, drop jump with 0.75 m height, back squat, and power clean using varied load and repetition. The distance ranged from 15 m to 100 m, and recovery duration from 1 minute to 15 minutes. Due to these diverse findings of the previous studies, researchers suggest using individualized PAPE protocols for athletes. Figure 5 shows 25% of the subject did improve in 15 m sprints, which supports the previous observations that PAPE should be individualized when considering linear sprints.

An important concern to be noted in our study is an improvement in COD ability (MAT) but not in 15 m linear sprint performance, although MAT includes a total of 10 m linear sprints. Petisco et al. [32] had similar findings where they observed improvement in MAT performance but not in linear sprint performance. As per the authors' knowledge, the only study to incorporate a 15 m linear sprint test as a PAPE measure was by Winwood et al. [47] who used 15 m and 7.5 m sled pull with loads of 75% body mass and 150% body mass. Significant improvements were observed with 15 m sled pull with 75% body mass load and not in 7.5 m sled pull with 150% body mass. Winwood et al. [47] suggested providing adequate recovery of about 8 to 12 minutes for improving 15 m sprint performance. Our study provided a recovery duration of 3 minutes from the BDJ protocol to assessment which may not be adequate to induce PAPE in 15 m linear sprint. Another possible reason for this finding in our study may be due to fatigue while performing two trails of MAT before the 15 m sprint test. This may be addressed in future studies by conducting only linear sprint tests at different recovery interval following BDJ protocol.

This study has shown that combining slow and fast SSC ballistic activity provides an effective strategy for acutely improving MAT performance. Individualization of PAPE for COD ability may not be necessary for BDJ protocol with appropriate box height, as all the subjects in this study showed some improvement after BDJ (Figure 4), although individualization of box height or volume may be more beneficial and requires further studies. In contrast to this, our study also supports the previous findings that conditioning activity should be individualized when linear sprinting is a priority.

Conclusions

The results of this study suggest that BDJ protocol, specifically 3 sets of 5 repetitions is capable of inducing PAPE during MAT with a short 3 minutes recovery duration. Although boxes with varying height have been extensively used by many strength and conditioning coaches to perform box jumps or drop jumps separately, this is the first study to combine both the exercises into one and find possible benefits. Coaches may use box height of 0.65 m after specific warm-up to induce PAPE and gain maximal benefits. Also, the long-term effect of BDJ exercises on different performance measures can be further studied.

Conflicts of Interest

The authors declare no conflict of interest.

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Effectiveness of explosive sprint and pedaling exercises for physical fitness assessment of throwers

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Abstract
Introduction. **The reliability of the 30-m sprint and bicycle ergometer tests, which are widely used as an indicator of the explosive muscle capabilities of the leg, has not been studied for the physical fitness assessment of throwers.** Aim of Study. **This study aimed to clarify whether the sprint and bicycle ergometer tests at short operating times are useful for assessing the competitive performance in the throwing competition.** Material and Methods. **For 11 male university students, the highest rotation speed (1, 2, 3 s each) was measured at three different loads during a 10-yd running time and bicycle ergometer test (1, 2, 3 s each). The relationship between the measured value and the competitive force (IAAF score) was examined.** Results. **The results can be summarized as follows: 1) no significant correlation was found between the 10-yd sprint time and athletic performance. 2) A positive correlation between the body mass and the number of revolutions was found so that weight positively affects the maximum rotational speed. 3) A positive correlations were found between the maximum numbers of revolutions at 3 s for each loading condition.** Conclusion. **These results suggest that (1) the sprint test is unsuitable for throwers, and (2) the maximum pedaling speed for a short period (1.0-2.0 s) with a relatively high load (5.0 kgf) is useful.**

KEYWORDS: 30-m sprint test, bicycle ergometer, physical fitness assessment, throwers.

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Introduction

For a thrower, increasing the release velocity is crucial [2, 3, 6, 7, 9, 11, 17, 18] for distance determination. Field tests are important as events reflecting the specificity of the sport [13]. As explosive muscle strength is required for the thrower, field tests can be performed as an evaluation method. Field tests have been used almost since the 1980s [4, 12]. For instance, backward throw [1, 10, 15, 20-23], standing long jump and standing triple jump [8, 10, 15, 20, 21]. However, the reliability of the 30-m sprint and bicycle ergometer tests, widely used as an indicator of the explosive muscle capabilities of the leg, has not been studied for the physical fitness assessment of throwers. Although some reports indicated that the 30-m sprint is a useful measurement event [23], no significant association exists with the athletic performance [20]. A useful report for the physical fitness evaluation discussing throwing in particular events was presented [15]; however, the relationships presented in the report are not effective for the physical fitness evaluation of hammer throwers [10]. In this regard, the following two problems could be why a unified opinion has not been obtained on the relationship between sprint and competitive abilities. First, whether the running time for a sprint distance of 30 m is appropriate or not is not clear for the physical fitness assessment of throwers. Studies using distances shorter than 30 m (20 yds, approximately 18.188 m [16])

or long distances (100 m [15]) have been reported. However, optimal distance has not been determined.
The second problem is the effect of the body mass of the thrower. For a thrower, a large physique is a beneficial factor, as well as having a great force to carry heavy objects. Therefore, sprint tests are considered not suitable for physical fitness evaluation because body mass negatively affects these tests. If this is the case, the bicycle ergometer that is not affected by body mass may be more suitable for evaluating physical fitness. The power ability of the bicycle ergometer is often evaluated through two variables: the maximum rotational speed and the maximum anaerobic power. In the maximum rotational speed test, the maximum rotational speed during pedaling at a lightweight load of 1.0 kgf is measured. Alternatively, in the maximum anaerobic power test, the maximum effort pedaling at 10 s is obtained through three sets between 60 s of rest at three loads that are gradually increased. A significant correlation between the athletic performance and the power ability measured was reported using a bicycle ergometer in the shot put [14] and the javelin throw [5]. Furthermore, conflicting results have been observed in studies based on multi-event throwers. A study measuring the power performance before and after the off-season for college students reported that the maximum anaerobic power showed a positive correlation with the athletic performance before and after the off-season. Moreover, the study reported that a positive correlation existed between athletic performance and the maximum rotational speed only before the off-season [19]. Aoki et al. [1] suggested that no association exists between the maximum anaerobic power and competitive ability. The problem of testing using a bicycle ergometer was the type of exercise because the throwing event requires assessing the instantaneous power. However, the maximum anaerobic power test and maximum rotational speed test were performed for approximately 10 s. Therefore, the characteristics of throw events require a method where the movement ends in a shorter time.
From these points, if the operation time of the sprint and bicycle ergometer test is set to a shorter time, it may become a reliable test. However, no research has focused on this regard. This study examines whether the sprint and bicycle ergometer tests with short operating times are useful for evaluating the athletic performance in throwing competitions.

Aim of Study

The purpose of this study was to clarify if the sprint and bicycle ergometer tests at short operating times are useful for assessing the competitive performance in the throwing competition.

Material and Methods

Subjects
The subjects were 11 male student-athletes specialized in throwing (age: 19.64 ± 0.88 years old, height: 177.49 ± 5.45 cm, weight: 92.29 ± 17.24 kg), 2 in discus throws, 2 in shot puts, 3 in hammer throws, and 4 in javelin throws. Moreover, the study considered 8 people who had participated in nationwide scale competitions and 3 people who did not. Five out of the former throwers had won the competition on a nationwide scale. To consider competition standards, we adopted the best score of the season in 2019. The competition standard was 786.00 ± 50.37 points in terms of the IAAF score.
The purpose and methods of the study were explained to the subjects. Informed written consent for the experiment participation was obtained. Before conducting the experiments, the Graduate School of Sports and Health Sciences, Juntendo University, received a research ethics review and obtained approval (No. 31-91).

Procedures and measurements
Measurement time and location
This experiment was conducted at Juntendo University Sakura Campus. The measurements were performed in three parts between February and March 2020.

Ten-yd sprint
An electric time gate (TCi Timing System, Brower Timing Systems) was used to measure the 10-yd sprint time. An electric time gate was installed at the height of 100 cm from the floor on the start and goal lines. The participants were prepared by setting the forefoot at the mark 30 cm behind the start line. The time was measured with a precision of one-hundredth of a second. The measurement was performed twice, and the best measured time was adopted.

Maximum rotational speed in the bicycle ergometer
Power MAX VIII (Konami Sports Co., Ltd.) was used to measure the maximum rotational speed in the bicycle ergometer. Three types of loads were used, namely, 1, 3, and 5 kgf. Three types of motion times were set for 1, 2, and 3 s at each load, and 9 events (1-kgf-1-s, 1-kgf-2-s, 1-kgf-3-s, 3-kgf-1-s, 3-kgf-2-s, 3-kgf-3-s, 5-kgf-1-s, 5-kgf-2-s, and 5-kgf-3-s) were measured. All the pedaling tests started from a stationary state. The participants were not allowed to lift their hips from the saddle when pedaling. The measurements were

performed randomly and separated by three days. The data was recorded twice for each measurement.

Statistical analysis
The statistics are shown as the mean ± standard deviation. Pearson's correlation coefficient was used to test correlations between measurements. Moreover, the risk rate was less than 5%.

Results

Ten-yd sprint
The average time of the 10-yd sprint was 1.67 ± 0.13 s (Table 1). No significant correlations were found between the 10-yd sprint time and the IAAF scores (Figure 1).
Maximum rotational speed in the bicycle ergometer
The results of the maximum rotational speed in the bicycle ergometer test are listed in Table 1.

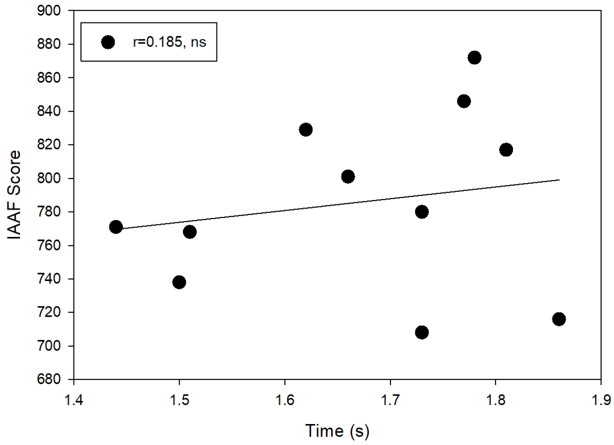


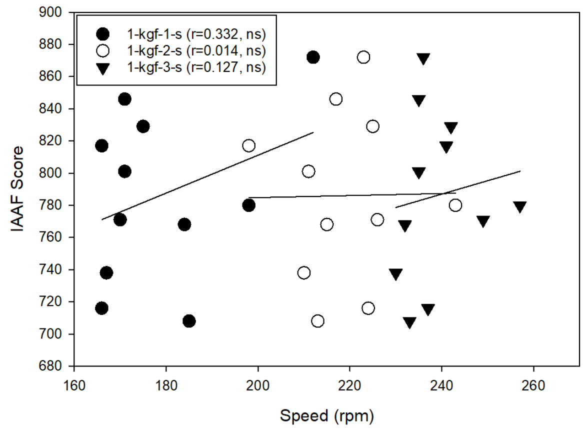
Figure 1. Correlation between the athletic performance and the 10-yd sprint

Table 1. Results from the 10-yd sprint and maximum revolution in the bicycle ergometer

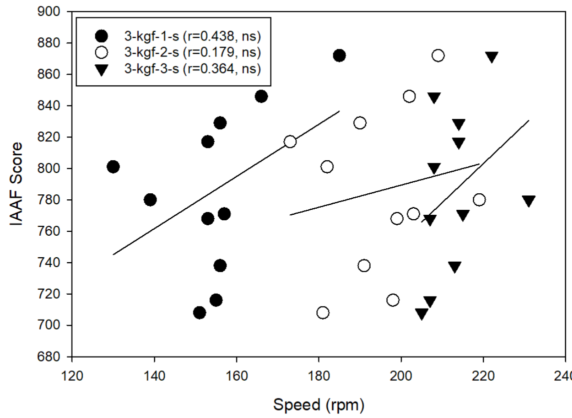
	Mean ± SD	Range (Min – Max)
1	2	3
10-yd, s	1.67 ± 0.13	1.44 – 1.86
1-kgf-1-s, rpm	178.64 ± 14.20	166 – 212
1-kgf-2-s, rpm	218.64 ± 11.05	198 – 243
1-kgf-3-s, rpm	238.82 ± 7.67	230 – 257
3-kgf-1-s, rpm	154.64 ± 13.25	130 – 185
3-kgf-2-s, rpm	195.18 ± 12.79	198 – 243
3-kgf-3-s, rpm	213.09 ± 7.37	205 – 231
5-kgf-1-s, rpm	139.27 ± 17.62	121 – 179
5-kgf-2-s, rpm	178.36 ± 17.22	138 – 206
5-kgf-3-s, rpm	194.18 ± 11.52	178 – 218

Note: 1-kgf-1-s indicates that subjects pedaled a cycle ergometer with maximum effort for 1 sec at 1 kgf; 10-yd – 10 yard sprint

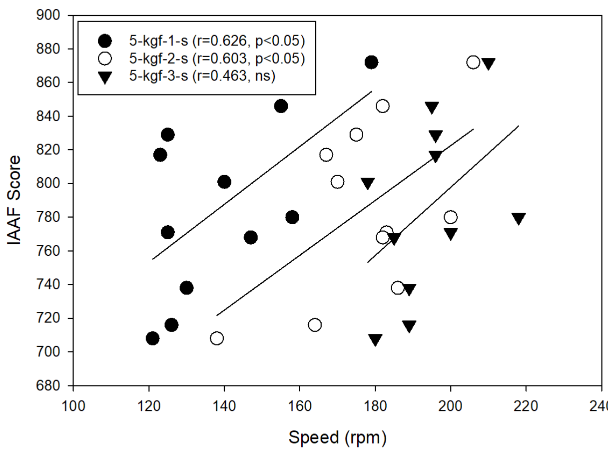
No significant associations were found between all measurement items for 1 kgf and 3 kgf and the IAAF scores (Figures 2 and 3). Conversely, significant positive correlation was observed between the maximum rotational speed in the bicycle ergometer and the IAAF score in 5-kgf-1-s ($r = 0.626$, $p < 0.05$) and 5-kgf-2-s ($r = 0.603$, $p < 0.05$) (Figure 4).



Note: 1-kgf-1-s – maximum effort for 1 s at 1 kgf; 1-kgf-2-s – maximum effort for 2 s at 1 kgf; 1-kgf-3-s, maximum effort for 3 s at 1 kgf
Figure 2. Correlation between the athletic performance and maximum effort at 1 kgf



Note: 3-kgf-1-s – maximum effort for 1 s at 3 kgf; 3-kgf-2-s – maximum effort for 2 s at 3 kgf; 3-kgf-3-s – maximum effort for 3 s at 3 kgf
Figure 3. Correlation between the athletic performance and maximum effort at 3 kgf



Note: 5-kgf-1-s – maximum effort for 1 s at 5 kgf; 5-kgf-2-s – maximum effort for 2 s at 5 kgf; 5-kgf-3-s – maximum effort for 3 s at 5 kgf, * $p < 0.05$

Figure 4. Correlation between the athletic performance and maximum effort at 5 kgf

Relationships between measured variables

The correlation coefficients between each measured variables are listed in Table 2. Body mass and 3-kgf--1-s ($r = 0.706$, $p < 0.05$), 5-kgf-1-s ($r = 0.668$, $p < 0.05$), 5-kgf-2-s ($r = 0.612$, $p < 0.05$), and 5-kgf-3-s ($r = 0.620$, $p < 0.05$) presented positive correlations. No significant correlations were found between the 10-yd sprint and any of the measurement variables.

At the maximum rotational speed in the bicycle ergometer, correlations were observed between multiple variables. Specifically, the highest correlation coefficients were found between 3-kgf-3-s and 5-kgf-3-s ($r = 0.924$, $p < 0.01$). Moreover, a positive correlations were found between the maximum numbers of revolutions at 3 s for each load in all combinations. Specifically the correlations were found for 1-kgf-3 vs 3-kgf-3 ($r = 0.747$, $p < 0.01$), 1-kgf-3 vs 5-kgf-3 ($r = 0.737$, $p < 0.01$), and 3-kgf-3 vs 5-kgf-3 ($r = 0.924$, $p < 0.01$).

Discussion

In this experiment, the hypothesis that the competitive capacities in a throwing competition can be evaluated by setting the exercise time shorter than the sprint and bicycle ergometer test was verified. Until now, the 30-m running test has been used for sprint tests. The results showed that even if the running distance is reduced to 1/3 of the 30-m running test, approximately 10 yds, the test would not be useful for the physical fitness assessment of throwers. Takanashi [19] noted that body mass is the reason for the lack of a significant correlation between the 30-m sprint time and competitive capacities. In this experiment, the general tendency that a positive correlation between the time and

Table 2. Correlation coefficient between the measured variables

	BM	10-yd	1-kgf-1-s	1-kgf-2-s	1-kgf-3-s	3-kgf-1-s	3-kgf-2-s	3-kgf-3-s	5-kgf-1-s	5-kgf-2-s	5-kgf-3-s
IAAF Score	0.608 *	0.185	0.332	0.014	0.127	0.438	0.179	0.364	0.626 *	0.603 *	0.463
BM		0.526	0.500	0.277	0.154	0.706 *	0.479	0.428	0.668 *	0.612 *	0.620 *
10-yd			0.175	0.020	0.012	0.146	0.059	0.054	0.229	0.089	0.163
1-kgf-1-s				0.487	0.201	0.365	0.574	0.595	0.765 **	0.463	0.563
1-kgf-2-s					0.687 *	0.002	0.855 **	0.625 *	0.355	0.432	0.656 *
1-kgf-3-s						0.246	0.483	0.747 **	0.071	0.389	0.737 **
3-kgf-1-s							0.288	0.093	0.420	0.367	0.350
3-kgf-2-s								0.624 *	0.661 *	0.707 *	0.724 *
3-kgf-3-s									0.515	0.753 **	0.924 **
5-kgf-1-s										0.743 **	0.559
5-kgf-2-s											0.785 **

Note: BM – body mass; 10-yd – 10 yard sprint; 1-kgf-1-s – maximum effort for 1 s at 1 kgf; 1-kgf-2-s – maximum effort for 2 s at 1 kgf; 1-kgf-3-s – maximum effort for 3 s at 1 kgf; 3-kgf-1-s – maximum effort for 1 s at 3 kgf; 3-kgf-2-s – maximum effort for 2 s at 3 kgf; 3-kgf-3-s – maximum effort for 3 s at 3 kgf; 5-kgf-1-s – maximum effort for 1 s at 5 kgf; 5-kgf-2-s – maximum effort for 2 s at 5 kgf; 5-kgf-3-s – maximum effort for 3 s at 5 kgf
* $p < 0.05$, ** $p < 0.01$

body mass of 10-yd sprints was present; however, it was not significant ($p = 0.096$). Moreover, the two subjects with the worst performance in the 10-yd runs were the heaviest people in terms of body mass. As one of them had multiple prizes in a nationwide competition, the sprint test is considered as unsuitable for evaluation in the field test. Conversely, for 3-kgf-1-s, 5-kgf-1-s, 5-kgf-2-s, and 5-kgf--3-s, the positive correlation between the body mass and the number of revolutions showed that weight positively affects the maximum rotational speed. In the relationship with the IAAF score, a positive correlation was found between 5-kgf-1-s and 5-kgf-2-s. Nevertheless, considering that the same relationship was not observed for 1 kgf and 3 kgf loads and 5-kgf-3-s, a short test at 5 kgf is considered to reflect the characteristics of the projection competition, which requires the projection of certain heavy objects in a very short time, rather than moving rapidly [10]. In this regard, it is interesting that the correlation coefficient with the IAAF score was high in the following order of 5-kgf-1-s> 5-kgf-2-s> 5-kgf-3-s. Moreover, a physical strength element different from the test of 3 s is required for the test of 3 s because a positive correlation was observed between the maximum rotational speed in the bicycle ergometer of 3 s for each load. No significant association with the IAAF score was found regardless of the difference in load during 3 s of pedaling.

These results suggest that the sprint test is not suitable for event throwers. The maximum pedaling speed for a short time (1.0-2.0 s) is useful at a relatively high load (5 kgf). In the future, it is necessary to consider pedaling tests with larger loads.

Conflicts of Interest

The authors declare no conflict of interest.

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The force, velocity, and power of the lower limbs as determinants of speed climbing efficiency

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Abstract
Introduction. **Speed climbing is different from the other climbing specializations because high efficiency in this competition is primarily determined by the high efficiency of lower limbs. The assessment of the magnitude of the relations between the level of force, velocity, and power of a single jump with the level of the specific-climbing power and time of a climbing run may have a high informative value.** Material and Methods. **Participants in the research were men (n = 8), taking part in the Czech Republic's Open formula speed climbing championships. Motor performance was measured using the countermovement jump (CMJ). The measurements were made with the use of My Jump application. The analyses assessed power, force, and velocity during a CMJ jump. The Margaria–Kalamen formula was used to estimate the special climbing power.** Results. **The data indicate that velocity, power, the height of the CMJ jump, and the special climbing power closely correlate with climbing time. Statistically significant correlations were noted between the special climbing power and velocity, power, and height of the CMJ.** Conclusions. **In speed climbing running time and climbing power is probably more strongly correlated with velocity, than the force component. My Jump app can become a worthy diagnostic tool, being able to provide information about kinetic parameters, which is highly valuable for speed climbing coaches.**

KEYWORDS: explosive capacities, lower limbs, Samozino et al. method, mechanical characteristics.

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Introduction

Speed climbing is one of three sub-disciplines of sports climbing (speed or lead climbing, bouldering). It consists of the fastest possible climbing on a 15-meter-long standard route with a slight slope. The research so far has shown that in terms of motor preparation, the leading speed climbers are characterized by a higher level of strength and speed abilities in comparison to other climbers [4, 9, 16]. Sprinting specialization compared to other climbing specializations is different because high efficiency is primarily determined by the high efficiency of the lower limbs [9, 16]. Accordingly, lower limb tests were mostly carried out in studies focused on strength and speed abilities in speed climbing. The jumping tests were usually standing broad jump [9] and/or countermovement jump (CMJ) using the Optojump system (Microgate, Italy) [10, 11]. The maximal anaerobic power of the lower limbs was estimated based on jumping tests results, and Sayers et al.'s formula [19]. The results of these studies clearly show the correlation between explosive strength and the maximal anaerobic power of the lower limbs with the running time in the speed climbing [10]. However, the above mentioned tests are significantly different from the specificity of movement in speed climbing.
Ozimek et al. [14] have attempted to develop a measurement method that allows the evaluation of

climbing movements in a unit of measurement other than the second. They proposed the Margaria–Kalamen formula (body mass × Earth's acceleration × distance/time) and video analysis as a useful tool to calculate the mean power of the climbing race [14]. Video analysis was also used to assess the power of the Chinese national team members' during the climbing race (body mass × Earth's acceleration × race speed). Based on these reports, one can talk about specific power in speed climbing. These studies show the possibility of evaluating explosive strength and anaerobic power in speed climbing based on jumping tests or video analysis. It should be emphasized that none of these methods provides information on force-velocity characteristics among speed climbers.

In light of those considerations, it seems that My Jump app could be used by speed climbing coaches to get information that is useful in practical terms [1]. This application provides easy low-cost measurements. Moreover, the My Jump app is used as a research tool in different athlete populations [3, 5, 7]. This device provides an accurate and reliable assessment of the level of muscles' mechanical parameters tested during the jump, i.e.: force (F), velocity (V), power (P), and height [6, 8]. The My Jump application delivers more data compared to devices previously used during tests in speed climbers.

It should be emphasized that so far researches conducted on the force-velocity profile of climbers were rare. Most frequently, the force and velocity capabilities of the upper limbs of climbers of various specialties were compared. These studies found that boulderers were characterized by a higher level of explosive force when compared to other climbers [12, 13].

Planning this research, it was assumed that mobile measuring tools like My Jump app [1] could be used to diagnose performance at a general level (non-specific for climbing), e.g. by the CMJ jump, and determining its force and velocity parameters. So far no attempts have been made to determine which mechanical parameter, force (F) or velocity (V), determines more the result of special power and climbing time in speed climbing. The assessment of the level of force, velocity, and power of a single jump by the My Jump app and evaluation of the magnitude of the relations between these variables with the level of the special power and climbing time may have value for speed climbing coaches, in two aspects: 1) the informative aspect, because it allows for collecting data about the level of the mechanical parameters during CMJ test, and 2) the practical aspect because the application can be used as a replacement for more expensive devices and allows for conducting measurements in conditions prevailing in climbing centers. Therefore, the study aimed to verify practical and informative aspects of the My Jump application in the assessment of force, velocity, and power during the CMJ test among speed climbers, as well as the evaluation of correlations between mechanical parameters of the CMJ jump and specific climbing power and climbing time.

Material and Methods

Male participants of the Czech Championships Open in sports speed climbing in December 2017 were subjected to the research (n = 8, the mean calendar age was 20.9 years). The subjects came from the Czech Republic (n = 4), Poland (n = 3), and Kazakhstan (n = 1). They displayed a varied sports level (some regularly qualified for the final rounds of international competitions, some of them came in the third ten, and others took part at least in the national competitions). All those who agreed to take part in the measurements were informed about the course and purpose of the research. The measurements were carried out immediately after the competition, in compliance with the Helsinki Declaration.

The climbing sprint time measurement (without the start signal, only the time of a run was measured) used a system that enabled the calculation of the climbing run power according to the Margaria–Kalamen formula. This method had successfully been used earlier in the analysis of climbing sprints [14]. In our research, it was assumed that by using statistical tools rationally it would be possible to find an answer to the question of how variables characterizing general efficiency (force, velocity, power) explain and determine the specific skill (specific-climbing power).

During the research, the climbers had their body height – BH, body weight – BW, and fat mass percentage – FM% measured. During anthropometric measurements, an anthropometer ALUMET and the BC-730 Tanita (Tanita corp., Japan) scale were used. Overall efficiency was measured using the height of CMJ (cm).

The measurements, in compliance with the instructions of the test authors, were performed with iPhone 6s (Apple, USA) and My Jump software [1]. Measurements were taken from the same position and with the same distance from a participant (1.5 m). The app determined jump height using the equation: $h = t^2 \times 1.22625$ described by Bosco et al. [2]. The length of the lower limbs (distance from the great trochanter to tiptoe with maximal foot plantar flexion) and the distance between the greater trochanter and the ground level (at approximately 90º knee angle squat position) were also measured and entered into My Jump [8, 18]. CMJ power – P (W), muscle-generated force – F (N), and muscle shortening velocity – V (m/s) were used for the analyses. The study also used the climbing sprint results achieved by the competitors in the competitions (the shortest time in all races). The sprint results were used to calculate the run power RP (W/kg) according to the procedure described by the Ozimek team [14].

In the statistical analysis, the following values were used: arithmetic mean (x̃), standard deviation (SD), mean confidence intervals (95% CI), and coefficient of variation (CV). The relationships between the dependent variable (run time) and independent variables (force, velocity, and power indices) were evaluated with the use of Pearson's correlation (with 90% CI). A p-value < 0.05 was adopted as a statistically significant correlation. To check the normal distribution of variables the Shapiro–Wilk test was performed.

Results

Table 1 demonstrates descriptive statistics and correlation coefficients of the measured somatic features and indicators

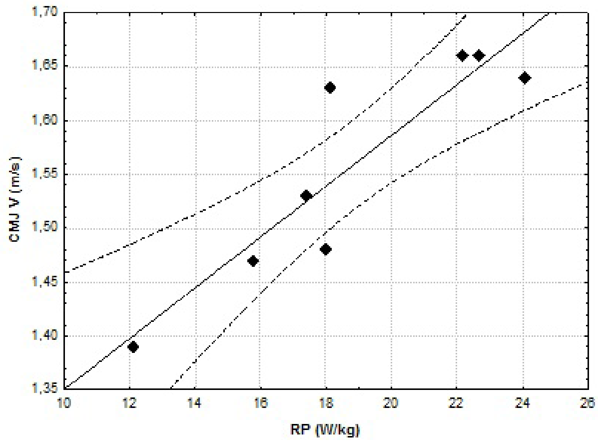

Figure 1. The scatterplot for the RP (W/kg) and CMJ V (m/s) with 95% CI

Table 1. Descriptive statistics and correlation coefficients (with CI) of the measured somatic features and indicators of motor skills with climbing sprint time and specific-climbing power

	x̃	SD	95% CI		CV	$r_{(x,y)}$ rt [s]	$r_{(x,y)}$ RP [W/kg]
rt [s]	8.19	1.95	6.56	9.81	23.79	1.00	–0.97* (p = 0.00) CI (0.97 ± 0.06)
BH [cm]	178.55	8.83	171.17	185.93	4.95	–0.44 (p = 0.26)	0.47 (p = 0.23)
BW [kg]	70.23	12.19	60.03	80.42	17.36	–0.44 (p = 0.26)	0.48 (p = 0.22)
FM [%]	8.39	2.54	6.27	10.51	30.27	–0.07 (p = 0.86)	0.06 (p = 0.88)
RP [W/kg]	18.78	3.98	15.46	22.11	21.17	–0.97* (p = 0.00) CI (–0.97 ± 0.06)	1.00
CMJ [cm]	49.56	6.35	44.25	54.86	12.81	–0.89* (p = 0.00) CI (–0.90 ± 0.18)	0.90* (p = 0.00) CI (0.90 ± 0.17)
CMJ F [N]	1603.98	210.43	1428.05	1779.9	13.12	–0.54 (p = 0.165)	0.55 (p = 0.15)
CMJ V [m/s]	1.56	0.10	1.47	1.64	6.67	–0.90* (p = 0.00) CI (–0.90 ± 0.17)	0.90* (p = 0.00) CI (0.90 ± 0.17)
CMJ P [W]	2501.85	407.34	2161.31	2842.39	16.28	–0.78* (p = 0.02) CI (–0.78 ± 0.32)	0.80* (p = 0.01) CI (0.80 ± 0.30)

Note: rt – climbing sprint time, BH – body height, BW – body weight, FM – fat mass percentage, RP – specific-climbing power, CMJ – countermovement jump height, CMJ F – muscle-generated force, CMJ V – muscle shortening velocity, CMJ P – CMJ power

* significant correlations

of the motor skills of the climbers. The data shows that special climbing power – RP, CMJ height (cm), P (W), and V (m/s) closely correlate with the running time. Statistically significant correlations between parameters and RP were recorded for: V (m/s) (0.9; $p < 0.05$), P (W) (0.80; $p < 0.05$) and the CMJ absolute score (cm) (0.9; $p < 0.05$). Figure 1 shows a diagram of the spread between RP (W/kg) and V (m/s) together with 95% CI.

Discussion

The My Jump application allows for an efficient assessment of the level of force, power, and velocity of the muscles working during a jump (CMJ) [5, 8, 15]. It needs to be highlighted that our research was the first attempt to use the My Jump application to evaluate force, velocity, and power in the CMJ test in speed climbers. Therefore, the question was whether the results collected by this application would have a reliable diagnostic value. For example, the Jiménez-Reyes et al. conducted similar measurements among sprinters and jumpers, with F, V, P on 1769 ± 129 (N), 1.61 ± 0.07 (m/s), and 2847 ± 317 (W), respectively [8]. Rago et al. study showed that among students, the mean value of velocity (V) obtained during the CMJ test was 1.42 ± 0.23 (m/s), with the mean height of the CMJ at 41 ± 0.4 cm [15]. Compared to these results the level of force, velocity, and power obtained in this research in speed climbers are similar and seem to be reliable. Some differences in mean values should be accepted as an effect of the sports specialization of the compared groups.

Previous research [10] in which the Optojump system (Microgate, Italy) was used demonstrated correlations between CMJ test, maximal anaerobic power, and best climbing time achieved during a national championship competition. The value of the correlations between the best climbing time and results for the CMJ test and relative power indicators were $r_{x,y} = –0.79$ and $r_{x,y} = –0.75$, respectively [10]. In our research, an attempt was made to analyze correlations of the force (F), power (P), and velocity (V) of the CMJ with the time of climbing and the climbing power (specific power; RP) indicator. A comparison of the correlation values from Krawczyk et al. study [10], with correlations from this study, shows that the strength of the correlations was similar. The correlation values between power obtained during CMJ and best climbing time were similar in both studies ($r_{x,y} = –0.75$ vs $r_{x,y} = –0.78$). Yet, correlation values between CMJ results and best climbing time were different ($r_{x,y} = –0.79$ vs $r_{x,y} = –0,89$), and higher in the present study. The high and significant values of the correlation coefficients observed in the present study show that the My Jump application and the CMJ test conducted with this application have a potentially high informative value in assessing the level of motor potential, training results, and possible results of competitions in speed climbing. The results of the present study (and other studies), low financial costs of buying the My Jump application, a lot of variables describing the motor potential of the climber, and the possibility of carrying out measurements in non-laboratory conditions (e.g. climbing training centers) emphasize a high practical value of the My Jump application for speed climbing coaches.

Moreover, data from our research indicate that fast climbing in this competition is more dependent on the speed component of the lower limb muscles. The amount of resistance (the body of the competitor, Earth's gravity) during a run is the load that makes the climbing run to qualify in the zone of maximum power and speed power. This means that the force and velocity profile of a speed climber can be oriented towards the velocity component. The F-v profiles of individual climbers were not determined in our research. Therefore, it is difficult to clearly state where exactly in the F-v curve the climbers under observation were located. Our results suggest that the velocity component may have more significance. Our unpublished measurements, made according to the procedure of Samozino et al. [17], concerning the F-v profile of a former world champion in speed climbing, being in the starting period, and qualifying for the final rounds, confirm the thesis about the profile characteristics. The profile of this competitor was velocity-oriented.

These results should be interpreted with caution. First, measurements were taken when the climber finished the competition. For this reason, the obtained results could be interrupted by fatigue or other psychosomatic factors connected with fatigue. Despite this, the participants were asked to perform maximum effort during jumping tests. Second, because of the small sample size (n = 8). Third, because of the high values of the standard deviation and coefficient of variance recorded for climbing time (rt) and specific-climbing power (RP), which indicate high dispersion in the studied group of climbers. Therefore, the correlation coefficients among rt, RP and CMJ, V (m/s), F (N) and P (W) could have been overestimated, and an actual influence on climbing time and climbing power competition values could be determined by technical skills, mental characteristics, and other factors not measured in this study. In the group of the tested speed climbers, a high level of homogeneity was observed for CMJ, V (m/s), F (N), and P (W) variables. This homogeneity also indicates that rt and RP variables could be determined by other abilities than strength and speed (for example: climbing technical skills, mental characteristics, etc.). Ozimek et al. [14] suggested that RP (W/kg) variable should be interpreted as a multivariate indicator, determined by strength and speed abilities, specific climbing movement skills, and mental predispositions. Therefore, correlating results of the CMJ test and its kinetic parameters, can answer the question: to what extent, in the studied group of climbers, RP was determined by explosive strength (the result of CMJ) and mechanical parameters of CMJ (force, velocity, and power)? This would make it possible to differentiate strength and speed factors from other, not measured factors, which together determine rt (s) and RP (W/kg) in speed climbing competition. In this study, the R^2 values for the correlations between rt (s) and RP (W/kg) and CMJ and V (m/s) were 81% in both cases. For P (W) and F (N), the values of R^2 were 64% and 31% respectively. Even with the potentially high impact of other factors, these results suggest that climbing time as well as specific-climbing power may be strongly correlated with speed abilities.

The results of this study may have a practical value for the training process in speed climbing because: 1) it enables trainers to obtain information on the velocity component of movement, which is important in speed climbing (and it is more difficult to train than the force or power); 2) it could be used in the speed climbing training, as it should contain non-specific and specific exercises at high velocity of movements (e.g. specific exercises on the climbing wall); 3) it suggest, that velocity oriented exercises should occupy 4/5 of all training time in speed climbing (based on R^2 values).

However, these indications, along with the current state of research in this discipline, should be regarded as suggestions. Further research in speed climbing should include an attempt to determine the full F-v characteristics of a climber.

Conclusions

In conclusion, our research reviled that My Jump app could become a worthy diagnostic tool, providing information about speed abilities, which is highly valuable for speed climbing coaches. Moreover, the motor effect, expressed by climbing time and climbing power in speed climbing, is probably more strongly correlated with velocity, than the force component.

Conflicts of Interest

The authors declare no conflict of interest.

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Match statistics significant to win the initial and intense rounds of a tennis tournament

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Abstract
This paper analyses the initial and intense rounds of the 2020 Australian Open Men's Singles matches on 14 match statistics. The findings show that the statistics which are important to winning in the initial rounds are not the same as those for winning in the intense rounds. In the initial rounds, the match winner performed better than the loser on receiving points won, second serve to win, first serve to win, breakpoints won, net points won, winners, total points won, unforced errors, aces, double faults, fastest serve speed, and average first-serve speed. However, to win the intense rounds, the winner performed better than the loser on first serve to win, receiving points won and net points won. The findings help the player and the coach to develop skills and techniques to devise a player strategy during the initial rounds and the intense rounds to win the tournament.

KEYWORDS: Australian Open, tennis, player's strategy.

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Introduction

Today, the game of tennis is played on a scale where millions are participating from 200+ nations affiliated to the International Tennis Federation (ITF) [23]. The game has evolved from its inception, with its roots buried deep in history. Tennis has been inscribed on the wall of Egyptian temples which date back to 1500 B.C. It was adopted by the Europeans when Moors invaded Europe and brought the game along with them. The game traveled with Christian monks who spread it in European monasteries and by the 18th century, it became a game played by aristocrats and royals. Tennis was then called 'real' tennis or 'royal' tennis. The first court for tennis was developed by King Henry VIII in the 19th century and in 1877, the All England Croquet and Lawn Tennis Club in Wimbledon organized the first lawn tennis tournament [9].

Over the years it was found that for a sport like tennis it is important to build and maintain self-confidence. Players having high self-confidence, experience lower anxiety and stress levels, which helps them maintain their concentration and focus which in turn results in better performance [3]. The progress of a tournament also increases fan attendance, ticket prices, and player rankings, with the level of the game having a positive effect on each other. From an economic point of view, it can be compared to the Louis-Schmelling Paradox which states that when there is the uncertainty of outcome in a tournament and the quality of the game portrayed is high, the resultant profits to be made on such events increases as it creates a doubt in the minds of spectators about the outcome [18].

In the four most competitive tournaments which constitute the Grand Slam, there are 32 top-seeded players. The seed order is based on a formula that considers the player's performance on that court surface and player rankings which indirectly influences the quality of the match.

Further, the prize money, points, and prestige associated with the tournament create a very high incentive for players to perform at their best [6]. In recent times, the top rankings are dominated by Rafael Nadal, Novak Djokovic, and Roger Federer. In 2019, Rafael Nadal won the French Open and the US Open, Novak Djokovic won the Australian Open and the Wimbledon. Novak Djokovic defended the Australian Open title in 2020. The competitive nature of the sport coupled with large overall benefits and returns makes every player dream of winning all four tournaments of the Grand Slam.

It was earlier thought that good service is the hallmark of a winner. However, it is not necessary that the serve alone can make a player win a match [15]. A player is likely to lose more points through errors and lose the match than by the points won by the match winners [2]. An experienced player is not always the winner when they face young players as young players have greater energy levels thus reducing the probability of winning [14].

Many studies have been conducted on what makes a player win a match or the tournament. To win a match, players must keep their first and second serves in, win on their services, and breakpoints [19]. Winners had lower double faults and unforced errors, were aggressive, approached the net, had a higher percentage of points won, and were capable of portraying a higher game level for the entire match [8]. To win a Grand Slam tournament, the player must be better at creating and winning breakpoints, winning on serve, applying higher serve speed, netplay, and reduce the number of errors [7]. In the French Open and Wimbledon tournaments, match winners were better on a percentage of points won on the opponent's service, percentage of points won on their own first and second serve, percentage of winning breakpoints, percentage of winning net points, and serving aces and number of winners [12].

Tennis, like other competitive sports, is as much about the mind as the body, with 95% being a matter of the mind [21]. Many players are affected by pressure, being unable to convert their advantage into a win, exhibit slippages, a behavior of giving up when they are behind or being unable to perform in crucial situations, and make unpredictable errors which can often be in the nature of blunders [13]. Players with low self-confidence buckled under pressure due to heightened anxiety and stress while those with high self-confidence displayed lower levels of anxiety and stress, enabling them to concentrate and focus on the game to produce better performance [3]. A player could become aggressive when he is close to losing the match due to the high anxiety situation. Uncertainty of match outcome is highest when the scores are tied and can result in an unforced error (if the player is balanced), a forced error (if the anxiety level is high), or in a win (if the self-confidence is high) [20].

Aim of Study

Previous studies drew inferences based on match performance for the entire tournament [3, 8, 19, 20]. Some researchers have analyzed the performance of players across tournaments over varying periods [7, 12, 13, 14]. The aim of this study was to ascertain which match statistics are more relevant to determine the outcome of a tennis match during the initial rounds (rounds 1-4) and the intense rounds (quarters, semis, and finals) of a tournament.

Material and Methods

The Men's singles matches of the 2020 Australian Open were chosen for analysis, being the most recent Grand Slam tournament. It consisted of 128 players and 127 matches. Data on 14 popularly quoted match statistics were accessed from the Australian Open website [22]. The 14 match statistics are the number of aces, winners, double faults, and unforced errors, percentage of the first serve in, first serve to win, second serve to win, breakpoints won, net points won, and receiving points won, number of total points won, and the fastest serve speed, average first-serve speed, and average second serve speed. The match statistics are defined in Table 1.

Table 1. Definition of match statistics

Match statistic	Meaning
1	2
Ace	A point won on serve, where the receiver is not able to touch the ball
Winner	An outstanding point where the receiver is unable to return
Double fault	When a player commits fault on both serve chances
Unforced error	An error made on part of the player which forces him to lose a point
Break point won (%)	The point before when a player wins the game on the opponent's serve
Receiving point won (%)	When a player wins a point on the opponent's serve
Net points won (%)	A point played from near the net
Total points won	Total points won by a player for the entire match
First serve in (%)	The total points played on the first serve
First serve to win (%)	The total points won on the first serve

1	2
Second serve to win (%)	The total points won on the second serve
Fastest serve	The speed of the fastest serve in a match
Average first serve	The average speed of the first serve in a match
Average second serve	The average speed of the second serve in a match

Source: [24]

The match statistics for the entire tournament, for the initial rounds, and the intense rounds were analyzed using IBM SPSS Statistics 24. Significance of match statistics for the entire tournament, initial rounds, and intense rounds was found through Mann–Whitney U test. The value of significance was ranked from smallest to largest to determine the importance of match statistics at various stages of the tournament. Significant match statistics for the intense rounds were analyzed using values of match statistics for the respective matches.
The top 32 seeds of the tournament had a World Ranking from 1 to 35 [1], while of the 8 players who qualified for the intense rounds, the World Ranking was 1, 2, 3, 5, 7, 15, 35, and 100. This reflects the competitive nature of the tournament of the intense rounds. The results were then analyzed and discussed for the intense rounds to infer what it takes to win the tournament.

Results

The mean and standard deviation values of each of the 14 match statistics along with the significance values derived using the Mann–Whitney U test are shown in Table 2. The results show that for the overall tournament, 12 match statistics of aces, winners, double faults, unforced errors, first serve to win, second serve to win, net points won, breakpoints won, receiving points won, total points won, fastest service, and average first serve were significant ($p < 0.05$) while 2 match statistics of the first serve in and average second serve were not significant ($p > 0.05$). Further, 10 match statistics of aces, winners, double faults, unforced errors, first serve to win, second serve to win, breakpoints won, net points won, receiving points won and total points won were also significant at 99% ($p < 0.01$).
For the initial rounds, 12 match statistics of aces, winners, double faults, unforced errors, first serve to win, second serve to win, net points won, breakpoints won, receiving points won and total points won, fastest service, and average first serve were significant ($p < 0.05$) while 2 match statistics of the first serve in and average second serve were not significant ($p > 0.05$). These results are consistent with the significance of the overall tournament match statistics. Further, 10 match statistics of aces, winners, double faults, unforced errors, first serve to win, second serve to win, breakpoints won, net

Table 2. Significant values of match statistics

Match statistics	Entire tournament		Initial rounds		Intense rounds	
	Mean ± SD	Significance	Mean ± SD	Significance	Mean ± SD	Significance
First serve to win (%)	0.717 ± 0.112	0.000	0.716 ± 0.114	0.000	0.735 ± 0.055	0.025
Receiving point won (%)	0.318 ± 0.088	0.000	0.318 ± 0.090	0.000	0.321 ± 0.034	0.028
Net points won (%)	0.667 ± 0.139	0.000	0.664 ± 0.139	0.000	0.736 ± 0.112	0.041
Number of aces	10.071 ± 7.368	0.001	9.950 ± 7.428	0.000	12.143 ± 6.100	0.073
Number of double faults	3.472 ± 2.616	0.002	3.471 ± 2.664	0.006	3.500 ± 1.653	0.100
Number of winners	38.012 ± 16.635	0.000	37.563 ± 16.760	0.000	45.714 ± 12.375	0.125
First serve in (%)	0.638 ± 0.087	0.172	0.636 ± 0.088	0.212	0.673 ± 0.070	0.401
Total points won	112.075 ± 37.081	0.000	111.029 ± 37.458	0.000	130.000 ± 24.457	0.443
Average first serve speed (kmph)	182.512 ± 18.849	0.037	182.042 ± 19.208	0.039	190.571 ± 7.583	0.607
Second serve to win (%)	0.508 ± 0.114	0.000	0.510 ± 0.116	0.000	0.476 ± 0.047	0.701
Number of unforced errors	37.295 ± 16.256	0.000	37.138 ± 16.386	0.000	40.000 ± 14.077	0.701
Fastest serve speed (kmph)	202.614 ± 20.779	0.015	202.279 ± 21.214	0.010	208.357 ± 9.572	0.796
Break points won (%)	0.372 ± 0.228	0.000	0.375 ± 0.232	0.000	0.326 ± 0.142	0.898
Average second serve speed (kmph)	151.799 ± 17.220	0.078	151.488 ± 17.570	0.057	157.143 ± 7.941	1.000

points won, receiving points won and total points won were also significant at 99% ($p < 0.01$). These results are also consistent with the significance of the overall tournament match statistics.

The results also show that of the 14 match statistics, two of them, viz., first service in and average second serve were not significant for the entire tournament, the initial rounds, and the intense rounds.

For the intense rounds, 3 match statistics: the first serve to win, receiving points won and net points won were significant ($p < 0.05$) − but not significant at 99% ($p < 0.01$) − while 11 match statistics of aces, winners, double faults, unforced errors, first serve in, second serve to win, breakpoints won and total points won, fastest service, and average first serve and average second serve were not significant ($p > 0.05$). The results show that the performance of the players in the initial rounds is also a reflection of the overall tournament performance. However, in the intense rounds, only three match statistics were important for winning as compared to 12 match statistics in the earlier rounds. This shows that while the match outcome is a function of many performance measures in the initial rounds, in the intense rounds, only a few performance measures are significant. The lower-ranked players get eliminated as the rounds progress, creating competitively balanced matches. For competitively balanced matches the critical match statistics that decide the outcome are winning on the first serve, winning more receiving points, and winning the net points.

Discussion

Match statistics that can help a player reach intense rounds of a tournament are aces, winners, double faults, unforced errors, first serve to win (%), second serve to win (%), breakpoints won, net points won, receiving points won, total points won, fastest serve speed and average first-serve speed. Analyzing the significance of match statistics, it was found that players must focus on the match statistics of receiving points won, second serve to win, first serve to win, breakpoints won, net points won, winners, total points won, unforced errors, aces, double faults, fastest serve speed and average first-serve speed in decreasing order of importance to win in the initial rounds (see Table 3 which ranks the match statistics on the significance values). In the intense rounds, the match statistics like first serve to win, receiving points won, and net points won in decreasing order of importance help winning the match. An important point to note is that winning on the second serve and the number of breakpoints won which were in the top 5 significant match statistics in the initial rounds were not significant in the intense rounds. This is due to the higher competitive balance of the match in the intense rounds. However, in the intense rounds, the relevance of serving aces, having fewer double faults, and getting the first serve in is more important than in the initial rounds.

Players' performance in the initial and intense rounds can be explained by their profiles [13] where many players are good at some aspect or match statistic of the game but not on many of them. Kovalchik and Ingram [13] classified players as 'The Field' which represent the largest number of players and who are most vulnerable to pressure situations, 'Tiebreak Specialists' and 'Tight' players who excel only in a critical situation, distinctive players who have a strong service or can face pressure situations and 'Score Keepers' whose play varies with the performance on the earlier point. In the initial rounds, such players demonstrate short bursts of excellence or are good on a few of the match statistics. The outcome depends on which of the two players performs better on the 12 significant match statistics. Further, tournament winners are 'Champions' and 'Opportunity Makers' who perform consistently across the match statistics. In the initial rounds when the competitive balance tends to be low, the player who is better across a variety of match

Table 3. Ranks of significant values

Match statistics	Entire tournament	Initial rounds	Intense rounds
First serve to win (%)	2*	3*	1*
Receiving point won (%)	1*	1*	2*
Net points won (%)	5*	5*	3*
Number of aces	9*	9*	4
Number of double faults	10*	10*	5
Number of winners	7*	6*	6
First serve in (%)	14	14	7
Total points won	6*	7*	8
Average first serve speed	12*	12*	9
Second serve to win (%)	3*	2*	10
Number of unforced errors	8*	8*	11
Fastest serve speed	11*	11*	12
Break points won (%)	4*	4*	13
Average second serve speed	13	13	14

* $p \leq 0.05$

Table 4. Significant match statistics during intense rounds

Round	Match	Player name	W/L	First serve to win (%)	Net points won (%)	Receiving points won (%)
Finals	1	Novak Djokovic	W	76%	83%	36%
		Dominic Thiem	L	69%	74%	29%
Semis	2	Dominic Thiem	W	77%	85%	33%
		Alexander Zverev	L	68%	71%	33%
Semis	3	Novak Djokovic	W	73%	92%	39%
		Roger Federer	L	66%	67%	31%
Quarters	4	Rafael Nadal	L	69%	62%	31%
		Dominic Thiem	W	78%	76%	34%
Quarters	5	Alexander Zverev	W	76%	69%	33%
		Stan Wawrinka	L	69%	70%	30%
Quarters	6	Roger Federer	W	71%	67%	29%
		Tennys Sandgren	L	79%	72%	33%
Quarters	7	Novak Djokovic	W	86%	91%	34%
		Milos Raonic	L	72%	51%	25%

statistics is likely to win the match. However, when 'Champions' and 'Opportunity Makers' play against each other, since the competitive balance is high as the players are evenly matched, the three match statistics found to be significant in the intense rounds become the differentiators. This substantiates the finding that in the initial rounds 12 match statistics are significant to determine the outcome of the match while only 3 in the intense rounds.

An examination of the top 5 significant match statistics in the initial rounds (Table 3) shows that the strategy of the winners is to win on their serve whether by aces or by rallies, try and break the opponent's serve, and to play aggressively at the net. Hence, winners have an attacking strategy that forces the opponent to commit errors, which is also confirmed by Matinez-Gallego et al. [17]. Losers would have greater errors in total including unforced errors and double faults, implying that winners are efficient in winning points [7]. Further, the higher-ranked players have greater self-confidence in the initial rounds as the opponent tends to be relatively weaker. This also results in lower player anxiety and stress levels, higher concentration levels, and maintain focus which helps to increase performance [3].

In the intense rounds, the players face increasing levels of stress and anxiety due to greater competitive balance [3]. The level of stress increase as the event progresses and creates demands on a person [4]. Similarly, anxiety is a situation when a person is threatened by the outcome of an event [11, 16]. As competitive balance increases in the intense rounds, there is a greater expectation from spectators' consequent to the uncertainty of an outcome of the match [18]. With increasing stakes, players often face increasing pressures which reduces performance [5]. An examination of the top 5 match statistics in the intense rounds (Table 3) shows the player's strategy is to ensure they win on their services and also win on the opponent's serve. This confirms the views of Djurovic, Lozovina, and Pavicic [7], Furlong [10], and O'Donoghue [19].

Each match of the intense rounds was analyzed on the three significant match statistics for these rounds. It was found that in 5 of the 7 matches, the winners were better than the losers on each of the three match statistics (see Table 4, Matches 1, 2, 3, 4, 7). In other words, winners of the 5 matches were better in first serve wins, receiving points won and net points won as compared to the losers. For the remaining 2 matches, it was found that in 1 match (Match 5 in Table 4) the winner was better on 2 match statistics and the loser was marginally better on the third match statistic while in the remaining match (Match 6 in Table 4) the loser was better on all 3 match statistics as compared to the winner.

In Match 5 between Alexander Zverev (World Ranking 7) and Stanislas Wawrinka (World Ranking 15), Zverev won the match with the score: 1-6, 6-3, 6-4, 6-2 [22]. The match statistic where the loser was better than the winner was net points won. Observing the match statistic closely, we have found that the winner converted 22 points from 32 opportunities that were created while the loser converted 16 points from 23 opportunities.

In Match 6 between Roger Federer (World Ranking 3) and Tennys Sandgren (World Ranking 100), Federer won the match with the score: 6-3, 2-6, 2-6, 7(10)-6(8), 6-3 [22] even though the loser was better than him in each of the three discussed match statistics. Katić et al. found that winners do not always need to perform better than the loser on each match statistic [12]. The fourth set was the turning point where the pressure levels increased for both players; for a player ranked 100 potentially winning against a player ranked 3 and for a player ranked 3 potentially losing against a player ranked 100. The match statistics strongly suggest that the loser should have won the match. However, the winner turned the tables and the match in the fourth set due to his profile being that of a Champion [13] wherein players exhibit the mentality of a champion and are strong in serves, are tiebreak specialists, are less affected by the state of the point, can create break point opportunities and have the ability to deliver during crucial situations. The loser appeared to have 'The Field' profile wherein players show a drop in performance when there is pressure on the service and are negatively affected when they are set down or facing important points such as tie-breaks or breakpoints.

This study will help players improve their game strategy and coaches train their players to improve their game. The players and coaches can use the findings of the initial rounds (Table 3) and work on improving the player's performance on the match statistics in reverse order of significance. The reverse order would enable them to train to improve the game using a strategic approach in a graded manner. They could begin by focusing on improving the service in terms of speed (ranks 11 and 12) and reducing double faults (rank 10). They can then focus on serving aces (rank 9), reduce unforced errors (rank 8), and focus on the total points won (rank 7). Thereafter, they can focus on ball placement to generate winners (rank 6), become aggressive by playing at the net (rank 5) followed by training to win breakpoints (rank 4). The final training would concentrate on winning the first and second serves (ranks 2 and 3) and winning points on the opponent's serve (rank 1).

After the player starts winning and qualifies for the intense rounds, the training should focus on the findings of the intense rounds. The player and the coach should focus on the ability to serve aces, having fewer double faults, and getting the first serve in as their relative rank is higher than in the initial rounds. Thereafter, the training could focus on becoming aggressive in playing at the net (rank 3), on winning points on the opponent's serve (rank 2), and on winning the first serve (rank 1).

Conclusions

In the initial rounds of a Grand Slam tournament, 12 match statistics out of 14 were found to be significant for winning a match viz., receiving points won, second serve to win, first serve to win, breakpoints won, net points won, winners, total points won, unforced errors, aces, double faults, fastest serve speed and average first-serve speed. As the tournament progresses and the lower-ranked players get eliminated, matches in the intense rounds are competitively balanced. This also requires the player to develop the qualities of a 'Champion' or an 'Opportunity Maker'. In the intense rounds, only 3 match statistics viz., winning on the first serve, winning more receiving points, and winning the net points were found to be significant for winning a match. These insights would help players improve their game and coaches to train their players to win important matches and tournaments.

Conflicts of Interest

The authors declare no conflict of interest.

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The assessment of longitudinal and transverse arching and load distribution in young women's feet

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Abstract
Introduction. **The human foot is an essential element of the musculoskeletal system. All foot shape irregularities may not only significantly impact the quality of life, but also cause serious afflictions and diseases in older ages. In addition, the lack of physical activity may adversely affect foot arching.** Aim of Study. **The objective of the study was to assess the extent of the foot arching and load distribution in sedentary female academic youth.** Material and Methods. **The study consisted of 20 physically inactive women aged 21 years. Foot arching was assessed with a CQ Electronic System podoscope, the analysis of the foot load was assessed with FDM-3 Zebris dynamographic platform.** Results. **The study shows that the female students had non-significant differences in longitudinal arching of the right and left foot. All women had the correct transverse feet arching. The percentage of load distribution on the right and left feet were within the scope of 50%. There were however significant statistical differences concerning a load placed on the forefoot and backfoot between the right and left foot.** Conclusions. **All analyzed students, according to Clarke's standards, had correct longitudinal and transverse arching of the foot, however, they showed differences in load distribution between the right and left foot and between forefoot and backfoot. The forefoot of the left foot and the backfoot of the right foot were more frequently loaded.**

KEYWORDS: feet arching, load distribution, female.

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Introduction

The human foot constitutes an essential static-dynamic link of the musculoskeletal system. On the one hand, it is a supporting element that allows balancing the body in the standing position, and on the other hand, it plays an important part in the gait mechanics. It is responsible for shock absorption which protects the spine and cranium from microtraumas [32]. The foot has its own specific internal and external architecture. Foot efficiency and its correct operation depends on the morphological structure and, more importantly, on the correct shape of longitudinal and transverse arches [13, 27].

Correct arching and load distribution of the feet are the basis for correct body posture and subsequent physical activity. The foot constitutes one of the links in the proprioceptive kinematic chain, therefore any irregularities occurring in shapes and functions of its segments may result in dysfunctions of other locomotor organs [6, 8]. Such dysfunctions include scoliosis, asymmetry in body parts position, and neurological diseases [21, 34]. It turns out that all the above disorders may influence the quality of life and wellbeing [20].

Apart from genetic factors and diseases, numerous environmental factors can affect the feet' growth and development. Quality and type of used shoes (often connected to fashion) are responsible for the majority of foot deformities and problems among students [14, 33]. The weakness of the muscles, ligaments, or bony arch-supporting structures can lead to the collapse of the arch [41]. Pathological flat feet can cause changes in muscle balance, gait, and alignment of joint motion [16]. Other factors possibly influencing the students' feet arching are diseases of the circulatory system, inflammations, keeping prolonged standing position, lack of attention to the hygiene and protection of the legs, or pregnancy [4, 19, 33].

The condition of feet also largely depends on the load, duration, and intensity of effort during sports training, as well as on the surface on which the exercises take place [3, 19, 43]. Bibro et al. [6] showed that in young men lower limb strength training has caused changes both in the foot loading pattern and the height of the longitudinal arching. In athletes performing taekwondo, handball, volleyball, athletics, football, wrestling, weightlifting, gymnastics, and swimming the irregularities of the longitudinal and transverse foot arches were determined [3, 19, 22, 44]. However, there are also studies, like Yi-Liang and Shen-Feng [43], where no changes in arches of the foot were observed between the basketball players and the sedentary control group. Some authors claim that physical activity improves foot arching and body posture. However, they also emphasize that inappropriate training load or exercise methodology may negatively influence the correct functioning and structure of the feet [19, 45].

In adults, excessive weight − frequently connected with the lack of physical activity − was shown to negatively affect foot structure and its function. These structural changes appear to be associated with increased foot discomfort and/or foot pain, which are significantly more often reported by overweight people compared to their leaner counterparts [5, 35]. It is identified that increased foot pain could act as a deterrent for obese individuals to participate in physical activity and in turn, perpetuate the cycle of obesity, as the base of support during most weight-bearing activities is feet [37]. Przysada et al. [31] while examining the students, have observed that feet disorders occurred more frequently in overweight persons. Adamczyk et al. [1] have concluded that persons with higher BMI are at higher risk of developing transverse flatfoot.

Feet health problems concern 71 to 87% of the population aged 18-33 [34]. It is the period between childhood and adulthood when people start taking care of their health by themselves [42]. Most of the problems that occur in middle and older age influence the quality of life in the elderly. However, problems in foot arching may begin in young adults – the question is why? Students belong to one of the most exposed groups to the occurrence of foot irregularities, and often have specific foot health issues that differ from those of other age groups, such as ankle sprains, tinea pedis, onychomycosis, plantar warts, and ingrown toenails [12, 15, 17, 23, 29]. Students are also subjected to different kinds of general changes, such as greater autonomy, control over their lifestyle, control over physical activity, and development of attitudes and beliefs about health and financial problems [24]. Even at this age, untreated foot problems can lead to scoliosis, postural problems, slower walking speeds, uneven plantar pressure distribution, difficulty in carrying out daily activities, increased risk of falling, and the appearance of neurological diseases [21]. Rodríguez-Sanz et al. [34] while examining a group of students aged 22, stated that their quality of life in terms of the feet' health was low, regardless of sex. Nevertheless, feet should be properly cared for and their condition should be regularly controlled since it prevents the occurrence and development of diseases, disorders, or infections. Despite the multi causality and scope of the issue, studies in the student groups that analyze feet defects and their health consequences, are conducted occasionally. Therefore, the aim of the study was to assess the parameters of foot arching and their load distribution in physically inactive young women.

Material and Methods

The study has been conducted in March 2015. The study group consisted of 20 women aged about 21 (21.3 ± 0.93), physically inactive – they didn't do any additional physical activity beyond that of daily living. Detailed characteristics of the group are presented in Table 2. Before the study, all participants were informed about the procedures and methods of the research, which was followed by their written consent to participate in the observation. Before starting the research, the students declared that they did not take any recreational physical activity for a year. The study was conducted in compliance with the Ethical Principles for Medical Research of the Helsinki Declaration.

The study inclusion criteria were: female, age 20-25, physically inactive, written consent to participate in the study, and to use the results for scientific purposes. The study exclusion criteria were: physically active women (women practicing competitive sports or performing at least 30 minutes of physical activity every day), neurological or orthopedic disorders occurrence, no consent for participation in the study.

Body mass accurate to 0.1 kg and body height accurate to 0.5 cm were measured with a calibrated electronic scale with a stadiometer (RADWAG, Zyrardow, Poland). The data was used to calculate BMI [36].

Longitudinal foot arching was assessed with a CQ Electronic System podoscope (podoscope, CQ Electronic

System, Czernica Wr., Poland) [10]. The device registered the image of the planta surface, and after defining the points, it calculated the foot arching parameters. The person being examined was standing on the device barefoot in a natural position with an even load distribution onto both feet. Next, the device registered the reflection of the planta surface and the computer recorded all the parameters taken. Based on the plantogram outcomes, longitudinal feet arching was assessed according to Clarke's angle [9]. The studies have shown that it is a sensitive and practical assessment measure of the feet arching [28]. Clarke's angle standards are presented in Table 1.

Table 1. Clarke's angle reference values

Clarke's angle values	Value interpretation
< 30º	flat feet
31-41º	feet with lower longitudinal arch
42-54º	correct longitudinal feet arch
< 55º	hollow feet

Based on the plantogram outcomes, transverse feet arching was assessed as well, with the use of Wejsflog longitudinal-transverse index 'Ww'. It evaluates the ratio between foot length and width. In the case of correct longitudinal arching, the foot length-width ratio should be 3:1, values closer to '2' indicated a transverse flatfoot [39].

Additionally, the following angles were defined: α angle – hallux position, β angle – little toe position, γ angle – heel position. Values below 0º both in hallux and little toe positions indicated varus position, and values above 7º indicated valgoid position. The correct heel position should be 15-18° [39].

For the evaluation of feet load and the force of foot base reaction, an FDM-3 Zebris dynamographic platform was applied (FDM-3 dynamographic platform, Zebris Medical GmbH, Am Galgenbuhl, Germany) [7]. The student took a natural standing position on the platform. Next, the distribution of load onto the forefoot and backfoot was registered, as well as total foot load.

All measurements were always taken by the same researchers, two times.

Statistical analysis

All data was collected into the Microsoft Excel program. To characterize the collected study data, basic measures of descriptive statistics were applied: mean ($\bar{x}$), standard deviation (SD), minimal and maximal values (Min--Max), median (Me). The normality of the distribution of the analyzed features was assessed with the Shapiro–Wilk test, whereas the significance of differences between right and left foot was measured with the Student's t-test. The adopted significance level was $p < 0.05$. Statistical calculations were made using the Statistica 13.0 program (Tibco, Palo Alto, CA, USA).

Results

The analysis of the somatic parameters shows that seventeen students had the correct body mass, two were underweight, and one was overweight. Table 2 shows the arithmetic mean, standard deviation, minimal and maximal values, and the median of the studied data.

Table 2. The somatic characteristics of the studied women

Parameter	$\bar{x}$ ± SD	Me	Min-Max
Age	21.3 ± 0.93	21.0	21.0-25.0
Body weight [kg]	58.2 ± 6.00	57.1	49.0-67.0
Body height [cm]	165.2 ± 4.92	165.5	156.0-174.0
BMI [kg/m^2]	21.2 ± 2.12	20.8	17.5-26.8

Note: BMI – body mass index, $\bar{x}$ – mean, SD – standard deviation, Min-Max – minimal and maximal values, Me – median

The students' feet arching data is presented in Table 3. Clarke's angle, which evaluates the foot arching, generally indicated the correct shape of the longitudinal arches; the differences were within 49.1º in the left foot and 51.9º in the right foot. It is worth to underline that one student had flat feet indicated by the average values, two students had hollow feet and the rest of the cases were within the applied standards. Seven students participating in the study had both feet correctly shaped. All the participating students had correctly arched both right and left feet.

The average values of the alpha angle determining the hallux position were 3.5º in the left foot and 3.9º in the right foot. Eight students had the correct hallux position, seven students were valgoid, and five varus. The average values of the beta angle determining the little toe position were within 12.8º in the left foot and 14.4º in the right foot. All the students had a valgoid position of the little toe. The average values of the gamma angle were 14.9º in the left foot and 15.5º in the right foot. The analyzed students had bilateral flatfoot (1 person), unilateral flatfoot (3 persons), correctly arched feet (7 persons), hollow feet (2 persons). Seven participants had one hollow foot and the other one correctly arched. In each case there were no statistically significant differences between right and left foot in terms of longitudinal arching (p = 0.267), transverse arching (p = 0.273), and hallux position (p = 0.349). However, significant differences were observed between right and left foot in the case of the heel position (p = 0.05), and little toe position (p = 0.03) (Table 3).

The testing of whether the transverse and longitudinal arching influenced the position of respective foot structures resulted in finding significant changes between the transverse arching of the right foot (p = –0.534) and left foot (p = –0.516), and the heel position (gamma angle) of both feet. It is possible that in this group of students the heel position might have been influenced by the transverse feet arching.

Table 3. Average values of parameters characterizing students' feet arching

Parameter	Foot	$\bar{x}$ ± SD	Me	Min-Max	p
Clarke's angle	*right*	51.9 ± 4.98	52.1	43.8-61.5	0.267
	left	49.1 ± 8.07	49.1	34.9-69.5	
'Ww' index	*right*	2.7 ± 0.12	3.0	2.6-3.0	0.273
	left	2.7 ± 0.11	3.0	2.5-3.0	
α angle	*right*	3.9 ± 5.32	4.0	(–2.7)-17.4	0.349
	left	3.5 ± 6.45	4.4	(–7.6)-14.7	
β angle	*right*	14.4 ± 4.74	15.4	7.4-23.8	0.030
	left	12.8 ± 3.85	12.1	5.6-20.9	
γ angle	*right*	15.5 ± 1.41	15.3	13.6-17.9	0.050
	left	14.9 ± 1.49	14.8	11.6-17.8	

Note: The Student's t-test, statistical significance p < 0.05; 'Ww' index – Wejsflog longitudinal-transverse index, α angle – hallux position, β angle – little toe position, γ angle – heel position, $\bar{x}$ – mean, SD – standard deviation, Min-Max – minimal and maximal values, Me – median

Table 4 includes the data presenting the participants' foot loading. There were significant differences concerning the load of the forefoot (p = 0.03) and backfoot (p = 0.04) between the right and left foot in the group of researched students. The significance of the total foot loading was not calculated since it is a distribution of 100% body weight pressure onto both feet. The average pressure force of the right forefoot was 51 N/cm^2 and was higher than the left forefoot load. In addition, the load force of both feet indicated that the right foot was more frequently loaded than the left one. More frequent loading (the median value) was observed in the forefoot of the left foot and the backfoot of the right foot. The analysis of the total load distribution onto the supporting surface shows that the right foot was more frequently loaded (60% of the participants) (Table 4).

Table 4. Average load distribution on the forefoot, backfoot, and whole supporting surface of the left and right feet

Parameter	Foot	$\bar{x}$ ± SD	Me	Min-Max	p
Forefoot	*right*	51.8 ± 15.64	51.5	17.0-74.0	0.03
	left	51.5 ± 18.68	56.5	19.0-78.0	
Backfoot	*right*	48.3 ± 15.68	48.5	26.0-83.0	0.04
	left	48.5 ± 18.68	43.5	22.0-81.0	
Total foot	*right*	52.8 ± 7.25	50.0	45.0-77.0	–
	left	47.2 ± 7.25	50.0	23.0-55.0	

Note: The Student's t-test, statistical significance p < 0.05; $\bar{x}$ – mean, SD – standard deviation, Min-Max – minimal and maximal values, Me – median

A detailed analysis of load distribution onto feet depending on the form of arching was conducted. As a criterion of the correct foot arching was Clarke's angle values within 42-54º.The correct longitudinal foot arching, both in the left and right feet, conditioned more frequent loading of the forefoot than the backfoot. The analysis of the whole right and left foot load shows that on average the load of both feet was correctly distributed.

In the group of participants with incorrect foot arching, there was a similarity of loading forefoot and backfoot of the right foot but in the left foot, the backfoot and forefoot were more frequently loaded. While comparing right and left foot loading, it has to be stated that in study participants with incorrect arching, the right foot was more frequently loaded.

Students with flatfeet, correctly arched feet, and hollow feet had the load distributed more onto the forefoot of both right and left feet. However, women with asymmetrical feet arching had the backfoot of both feet loaded more often than the forefoot. When it comes to the load distribution on the whole foot surface, students with flat feet and asymmetrically arched feet had the load distributed more onto the right foot whereas students with hollow feet had their left foot loaded more often. It is worth emphasizing that in the case of the correct longitudinal arching, the values of load distribution were the same for both feet.

Discussion

In our study, the differences were observed both in parameters typical for feet arching and loading. In each case, asymmetry was observed between the right and left foot. There were significant differences concerning a load placed on the forefoot and backfoot between the right and left foot. The alpha angle values were within the reference range, nonetheless, all students suffered from the little toe (beta angle) and heel valgus (gamma angle).

It was observed that Clarke's angle generally indicated the correct longitudinal arching of the feet. All women participating in the study had the correct transverse arching of both feet. Adamczyk et al. [1] reached the same conclusion. All the other participants had the correct longitudinal feet arching. Madejski et al. [23] found that among the group of 21-year-old students all had correct longitudinal feet arching. Puszczalowska-Lizis and Kwolek [30] conducted a study on 280 students aged 23 and observed that longitudinal flatfoot is not a commonly occurring defect in the academic youth. Yet, Przysada et al. [31] observed that the students had more frequently feet with lower arching and flat feet.

In our group of students, there were no statistically significant differences between right and left foot neither in terms of longitudinal arching and transverse arching nor in the hallux position. However, significant differences were observed between the feet in the heel position ($p = 0.05$) and the little toe ($p = 0.03$). More frequent loading was observed on the forefoot of the left foot and the backfoot of the right foot. The analysis of the load distribution on the whole supporting surface shows that the right foot was more frequently loaded. During the literature review, there was only one research found that differentiated the parameters of left and right foot arching in students. Mucha et al. [26] studying a group of 21-year-old students observed that the level of longitudinal feet arching was within the reference range for age and sex, whereas foot loading was not the same. It oscillated within 51.93-48.07% for the left against the right foot. The surface being loaded was smaller in the right foot, whereas the load distribution on the left and right backfoot was at a similar level [26].

The main area of interest for many researchers is the analysis of body weight and physical activity influence onto the feet arching and load distribution. The authors have shown that physical activity can cause changes both in the foot loading pattern and the longitudinal arching [3, 19, 22, 44]. Przysada et al. [31] and Adamczyk et al. [1] have proved that overweight and obese persons develop flat feet more often. All our study participants had correct body weight and, like 60% of the population, they didn't meet the minimum recommended daily physical effort [40], yet they had some differences in load distribution, which may affect their health in the future.

The limitation of the study was the small number of participants. It was a pilot study before implementing the observations to a larger student's youth group. Conducting the research in a bigger number of female students will probably minimize the error of statistical reasoning.

Future research recommendation may be the analysis of foot load performed not only in a static position but also in dynamic positions, such as walking, running, jumping. It could be worth verifying if and eventually how the measured parameters (typical for longitudinal arching and feet load) depend on the level of performed physical activity. The relation of "handedness" on the foot load distribution and foot arches is also worth future research.

Conclusions

Concluding, it seems essential to conduct research involving the factors causing changes in foot arching, diseases, and their structure's deformations. However, we analyzed young healthy students, who had correct longitudinal and transverse feet arching and hallux and heel position, they overloaded the forefoot of the left foot and the backfoot of the right foot and all suffered from the little toe valgus. These conditions, when untreated, will probably affect their feet' health in the future.

Conflicts of Interest

The authors declare no conflict of interest.

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Results: the results of biochemical assays and other measurements should be given in SI units. Length, height, weight, and volume measurements should be reported in metric units (meter, kilogram, liter) or their decimal multiples. Temperatures should be expressed in degrees Celsius. Enclose a maximum of 3 tables, 3 figures, and 3 photographs to illustrate your data. All tables, figures, and photographs must be referred to in the text of the manuscript.

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Abbreviation of the journal name should be used according to the list of journals indexed in Index Medicus.

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A citation of a journal article should include authors' names and initials without periods, the title of the paper, abbreviation of the journal name, year of publication, volume number, and page numbers (first and last page of the article).

1. Up to six authors: Halpern SD, Ubel PA, Caplan AL. Solid-organ transplantation in HIV-infected patients. N Engl J Med. 2002 Jul 25;347(4):284-287.
2. More than six authors – list the first six authors followed by et al.: Rose ME, Huerbin MB, Melick J, Marion DW, Palmer AM, Schiding JK, et al. Regulation of interstitial excitatory amino acid concentrations after cortical contusion injury. Brain Res. 2002;935(1-2):40-46.
3. Article published electronically ahead of the print version: Yu WM, Hawley TS, Hawley RG, Qu CK. Immortalization of yolk sac-derived precursor cells. Blood. 2002 Nov 15;100(10):3828-3831. Epub 2002 Jul 5.

Book citation

References to books should include surname(s) of the author(s) with first name initials (list the first six authors followed by et al.), title, number of an edition (not required for the first edition), city and name of the Publishing House and year of publication.

1. Gardiner PF. Advanced neuromuscular exercise physiology. Champaign: Human Kinetics; 2011.

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References to book chapters should include surname(s) of the author(s) of the chapter with first name initials without periods (list the first six authors followed by et al.), chapter title, and after indicating In: surname(s) of the author(s)/editor(s) with first name initials, the title of the book, number of edition (not required for the first edition), city and name of the Publishing House and year of publication followed by page numbers of the chapter, e.g.

1. Renson R. Sport Historiography in Belgium. Status and Perspectives. In: Renson R, Lämmer M, Riordan J, editors. Practising Sport History. Sankt Augustin: Akademia Verlag Richarz; 1987. pp. 1-18.

All titles and institutional names in languages other than English (including Greek, Polish, German, French, etc.) should be provided with their English equivalents, e.g.:

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Punctuation used in references must strictly follow the above examples.

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Each table should be on a separate A4 sheet, with a brief descriptive title at the top using the full word Table. All abbreviations should be explained in a footnote to the table where they appear. The tables should be numbered using Arabic numerals (1, 2, 3, 4, etc.).

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Figures and legends to figures should be provided in a single text file.

Abbreviations and symbols

Use only standard abbreviations and symbols. The expansion of an abbreviation should precede its first use

Table 1. Descriptive statistics and comparative analysis of maximal oxygen uptake (VO_2max in ml/kg·min^{-1}) between genotypes of the I/D *UCP2* gene polymorphism

UCP2		DD					ID					II			
Sex	*N*	$\bar{x}$	*SD*	*Min*	*Max*	*N*	$\bar{x}$	*SD*	*Min*	*Max*	*N*	$\bar{x}$	*SD*	*Min*	*Max*
F	42	45.65	*6.14*	32.30	59.00	36	45.66	*7.18*	30.60	59.80	7	45.07	*7.60*	35.00	54.80
M	72	54.01[a]	*6.20*	40.30	79.00	70	55.60	*7.32*	42.30	76.80	12	59.07[a]	*9.04*	49.70	74.90

in the text and be repeated in the legend under a figure or a table in which the abbreviation is used.
Papers that do not adhere to these guidelines will be returned to the author for corrections and improvements.

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