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Title: Acute effect of basketball-specific exercise on lower limb injury risk mechanisms in male basketball players U16 and U18

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Acute effect of basketball-specific exercise on lower limb injury risk mechanisms in male basketball players U16 and U18

Abstract

The aim of this study was to examine and compare the acute effects of basketball-specific fatigue on muscular stiffness and reactive strength in male adolescent basketball players of two age categories. Reactive strength, expressed by means of the reactive strength index (RSI), and leg stiffness (LS) as mechanisms associated with the risk of ACL injury were measured in eleven players of the U16 category (age 16.1 ± 0.4 years; body height 185 ± 6.5 cm; body mass 74.3 ± 9.9 kg) and ten players of the U18 category (age 17.7 ± 0.4 years; body height 187 ± 5.7 cm; body mass 79.7 ± 7.4 kg) pre and post simulated basketball match play (SBFP$_{28}$). RSI was determined by a drop jump test, LS by a 20 sub-maximal two-legged hopping test. No significant effects of SBFP$_{28}$ on the monitored parameters were observed with the exception of RSI in U16 (p = 0.013, r = 0.53). Similarly, there were no significant differences in the fatigue-related responses to SBFP$_{28}$ for RSI and LS between the age groups. These results indicated that irrespective of age, the stabilization function of the knee muscles was not impaired and consequently the risk of ACL injury was not increased.

Introduction

Basketball is a physically demanding sport, which imposes a highly variable load on the players [1]. Basketball performance combines maximum intensity activities and medium or low intensity multidirectional movements such as acceleration and deceleration, pivoting, dribbling, shuffling, jumping and landing, often performed unilaterally [2,3]. For these reasons, youth basketball belongs among risky sports with frequent lower limb injuries including injuries of the knee joint and hamstrings [4]. In 70 to 80 percent of cases, the injury is of a non-contact nature [5]. In particular, anterior cruciate ligament (ACL) injuries are associated with the longest interruption of training and competition, and also predispose to recurrence and other difficulties including earlier degenerative changes [5,6]. Non-contact ACL injuries appear to predominantly occur in a rapid change of direction initiated on one leg, landing from a jump on one leg, and pivoting [6-8].

It was proved that injury risk increases with chronological age and may also be related to important periods during growth and maturation [9]. It was recognized in youth athletes that 16 to 18-year olds represent a group at greatest risk where most injuries are likely to occur [10], which was also confirmed in sports such as basketball and soccer [11]. Other recent studies of youth reported the highest incidence of

injury in the group of 13 to 15-year olds, followed by 16 to 18-year olds [12], and the highest injury incidence around the time of Peak Height Velocity [13].

It was also documented that muscle fatigue is one of the modifiable risk factors of ACL injury [14,15]. Injury incidence data show an increased risk of injury towards the end of matches, when fatigue is most likely to be present [16]. There are a number of mechanisms that relate to an increased risk of knee injury and it was documented that muscular and neuromuscular control is important in reducing load on ACL and thus reducing the risk of ACL injury [17,18]. Fatigue decreases the neuromuscular component of the knee dynamic stability and thus increases the risk of ACL injury [19,20].

In fatigue-related prevention of ACL injuries, a significant indicator is muscle stiffness [21]. Information about lower limb stiffness is particularly important in terms of risk of injury resulting from a jump or change of direction impact [17]. Currently, there are only few studies focusing on the effect of fatigue on lower limb stiffness, mostly in soccer. Some studies claim that lower limb stiffness is compromised as a result of fatigue [22,23], while others report individualized changes in lower limb stiffness after a fatigue protocol [24]. It was also suggested that the influence of age on the ability to perform eccentric-concentric movements exists and that adults are capable of greater pre-activation and forward control compared with children and adolescents [25-27]. This suggests that children and adolescents represent a risk group in terms of injury [17].

Fatigue may also lead to changes in reactive strength of leg muscles [28]. The level of reactive strength in individuals is assessed by means of the reactive strength index (RSI). RSI represents an individual ability of transition from eccentric to concentric muscle contraction [29] and is determined for monitoring stress exerted on the muscle-tendon complex during plyometric exercise. RSI is also a significant indicator in the prevention of ACL injuries [30]. Studies dealing with the effect of age on the results of RSI point to gradually improving results during adolescence [26,27]. However, there are only few studies dealing with RSI as a result of fatigue in youth athletes, and on top of that with conflicting findings [23,31].

The above-mentioned findings on the occurrence of ACL injuries in team sports indicate that this is a serious phenomenon in which an important role playes the etiology of muscular and neuromuscular control, fatigue, and age. Nevertheless, there is a paucity of research on the influence of acute fatigue from match-play on physiological mechanisms in adolescent populations. Therefore, this study aims to examine and compare the acute effects of basketball-specific fatigue on muscular stiffness and reactive strength in male adolescent basketball players of two age categories.

Methods

Participants

The study involved a group of youth basketball players of the U16 category (N=11; age 16.1 ± 0.4 years; body height 185 ± 6.5; body mass 74.3 ± 9.9 kg) and U18 category (N = 10; age 17.7 ± 0.4 years; body height 187 ± 5.7 cm; body mass 79.7 ± 7.4 kg). The players trained on average six times per week and played one competitive match per week during the competitive season. All players tested were fully informed about the aim of the study and the testing procedures. The day before testing, the players were not exposed to any training load. The leg preferred for kicking was considered the dominant leg (DL) and the contralateral leg as the non-dominant leg (NL). The study was approved by the institution's ethics committee and conformed

to the Declaration of Helsinki regarding the use of human subjects. All players tested were free of any musculoskeletal lower-extremity injuries and were fully informed about the aim of the study and the testing procedures. A written informed consent to the testing procedures and the use of the data for further research was obtained from the players' parents.

Procedures

The measurements took place during the 2015 pre-season. During the first session, a week before testing, the players underwent anthropometric measurements, familiarization with the fatigue protocol, and the tests applied. During the second session, before the testing procedure, the players completed non-specific warm-up exercises, which included cycling on a stationary bicycle ergometer for 5 minutes at 1.5 W/kg, dynamic stretching exercises for six minutes, which targeted the main muscle groups involved during the test, and finally fifteen squats. The warm-up routine was performed under the researcher's supervision. The subsequent testing procedure consisted of measuring reactive strength, leg stiffness, and isokinetic strength. Then the players performed the fatigue protocol. Immediately after the fatigue protocol, the tests were repeated in the same order.

Reactive strength

The reactive strength index (RSI) was determined by means of a drop jump test with hands on the hips. The vertical jump performance was assessed using a portable optical timing system Optojump Next (Microgate, Bolzano, Italy) with manufacturer-declared accuracy of 0.001 s. The players jumped from a 30 cm high box in order to perform a maximum jump for the shortest period of take-off [32]. To familiarize the players with the testing procedure, two trials were performed followed by three measured attempts with a 30s rest interval between the sets. The greatest value of the three attempts was used in further analyses. RSI was calculated as the ratio between jump height and contact time on the floor [33].

Leg stiffness

To determine stiffness of the lower limbs, all players performed one trial set and two measured sets of 20 sub-maximal two-legged hopping using the Optojump Next system (Microgate, Bolzano, Italy) with hands on the hips and the torso in an upright position. The frequency of hopping was maintained at 2.5 Hz by using a mechanical metronome (Wittner GmbH & Co. KG, Isny, Germany). Of the two sets performed, the set in which the frequency of jumps was closest to the frequency determined by the metronome was selected. From this set, the ten consecutive jumps that were closest to the determined frequency of hopping were used for further analyses [34]. There was a 1-minute rest interval between the sets. Both absolute leg stiffness (ABSLS; $kN \cdot m^{-1}$) and relative leg stiffness (RELLS; $kN \cdot m^{-1}$), i.e. normalization of absolute leg stiffness according to leg length and body mass, were calculated [32].

Specific basketball fatigue protocol (SBFP$_{28}$)

The data are collected over four separate periods as in a match. There is a two-minute break following the first and third periods and a fifteen-minute break following the second period [35]. Each period consists of seventeen activity sections involving maximal activity (sprints), submaximal activity (running at 3 - 5m.s^{-1}), low intensity activity (jogging and walking at 1.5 – 3 m.s^{-1}) and standing (for 15 s). The first maximum intensity section starts when a whistle is blown and the time is measured by electronic timing gates

(PR1aW, Alge-Timing GmbH, Austria) with one-hundredth of a second accuracy. The scheme of the test is depicted in Figure 1.

Figure 1: Measured sections of SBFP$_{28}$ (Hůlka et al., 2017).
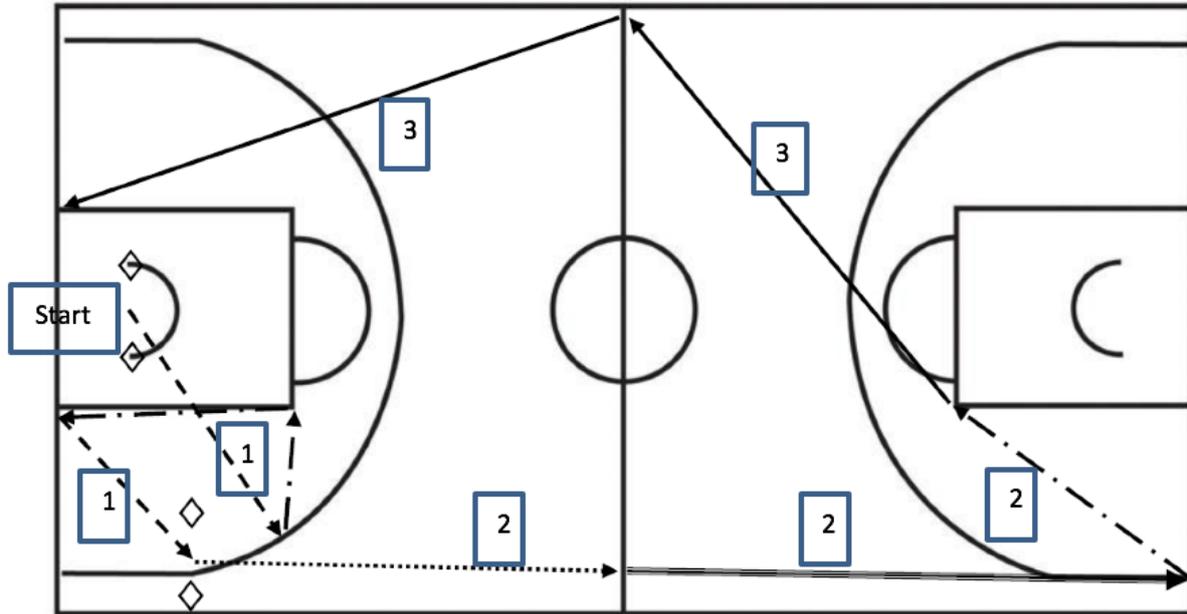
Legend: ◇ photocells; ⟹ backpedalling; ------▶ sprinting; ——▶ walking, –·–·–▶ shuffling; ·········▶ running; 1 = maximal intensity activity; 2 = medium intensity activity; 3 = low intensity activity.

Statistical analysis

The distributions of the data sets were checked for homogeneity and skewness using the Kolgomorov-Smirnov test. Descriptive statistics (means, medians and standard deviations) were calculated for all variables. Wilcoxon nonparametric tests were used to examine whether the basketball specific fatigue protocol led to significant changes in the variables observed. Mann-Whitney tests were used to compare the differences between the results of the U16 and U18 groups. The effect size was determined by the Cohen's *d* [36] and classified as small ($0.00 \leq d \leq 0.49$), medium ($0.50 \leq d \leq 0.79$), and large ($d \geq 0.80$). The significance level was set at $P < 0.05$. A statistical analysis was performed using the data analysis software system Statistica, version 12 (StatSoft, Inc., Tulsa, USA).

Results

The values of measured variables of the pre- and post- SBFP$_{28}$ and their changes for U16 and U18 groups of basketball players are reported in Tables 1 and 2. No significant effects of SBFP$_{28}$ on the monitored parameters were evident with the exception of RSI for U16 (p = 0.013, r = 0.53).

Table 1 Here

Table 2 Here

The between-group differences in the changes of the monitored parameters are reported in Table 3. There were no significant differences in the fatigue-related responses to SBFP$_{28}$ for any parameters between the groups.

Table 3 Here

Table 1: Monitored parameters of pre and post basketball specific fatigue protocol SBFP$_{28}$ in the group of U16 basketball players

Parameter	N	Pre test M±SD	Post test M±SD	% change	Z	*p*
ABSLS	11	26.65 ± 5.04	25.84 ± 4.48	96.9	0.533	0.594
RELLS	11	32.63 ± 7.28	31.35 ± 4.97	96.1	0.622	0.534
RSI	11	0.49 ± 0.08	0.54 ± 0.13	110.7	2.490	0.013*

Table Abbreviations: *N* – number of players, M – mean, SD – standard deviation, *ABSLS* – absolute leg stiffness, *RELLS* – relative leg stiffness, *RSI* – reactive strength index, *DL* – dominant leg, *NL* – non-dominant leg, *H/Q* – hamstring eccentric-to-quadriceps concentric functional ratio, *60* – angular velocity of 60°/s, *180* – angular velocity of 180°/s, Z – Wilcoxon test criterion, *significant difference between pre and post test (p < 0.05).*

Table2: Monitored parameters of pre and post basketball specific fatigue protocol SBFP$_{28}$ in the group of U18 basketball players

Parameter	N	Pre test M±SD	Post test M±SD	% change	Z	*p*
ABSLS	10	30.96 ± 6.68	29.56 ± 6.18	95.5	1.172	0.241
RELLS	10	35.29 ± 6.42	33.79 ± 6.58	95.8	1.070	0.284
RSI	10	0.41 ± 0.07	0.41 ± 0.07	100	0.050	0.959

Table Abbreviations: *N* – number of players, M – mean; SD – standard deviation, *ABSLS* – absolute leg stiffness, *RELLS* – relative leg stiffness, *RSI* – reactive strength index, *DL* – dominant leg, *NL* – non-dominant leg, *H/Q* – hamstring eccentric-to-quadriceps concentric functional ratio, *60* – angular velocity of 60°/s, *180* – angular velocity of 180°/s, Z –Wilcoxon test criterion.

Table 3: Differences in changes of monitored parameters of pre and post basketball specific fatigue protocol SBFP28 between the U16 and U18 groups

Parameter	U16 M	Mdn	SD	U18 M	Mdn	SD	*p*
Δ ABSLS 1-2	0.81	0.73	3.92	1.46	0.7	4.65	0.972
Δ RELLS 1-2	1.29	0.71	5.03	1.55	0.74	5.4	0.860
Δ RSI 1-2	-0.05	-0.03	0.06	-0.03	-0.03	0.03	0.503

Table Abbreviations: *N* – number of players, M – mean, SD – standard deviation, *ABSLS* – absolute leg stiffness, *RELLS* – relative leg stiffness, *RSI* – reactive strength index, *DL* – dominant leg, *NL* – non-dominant leg, *H/Q* – hamstring eccentric-to-quadriceps concentric functional ratio, *60* – angular velocity of 60°/s, *180* – angular velocity of 180°/s, Δ – absolute change.

Discussion

The main finding of the current study is that there were no significant age differences in the fatigue-related responses to SBFP28 for any of the parameters. Another finding is that SBFP$_{28}$, which was designed as a basketball-specific match simulation protocol, did not significantly compromise any of the observed parameters in any of the groups of youth basketball players. Oppositely, RSI values significantly increased in the U16 group. These results point out that after the basketball-specific fatigue protocol, the players' ability to effectively utilize neuromuscular mechanisms to control joint movement and reduce load on the ligaments was not compromised, which suggests that injury risk did not increase in the players of both groups due to simulated match-play.

The results of this study did not show fatigue-related changes in ABSLS or RELLS in the U16 and U18 categories. These results indicate that the fatigue protocol did not compromise neuromuscular pre-activation and neuromuscular feed-forward control (anticipation of known stimuli characterized by preventive muscle activity) as an indicator of dynamic stability of the knee. Thus it can be assumed that the ability of the muscles to resist movement within the tibiofemoral joint (tibiofemoral shear movements), which prevents ACL from being under strain [21] did not decrease.

Studies examining the effects of simulated match-play on muscular and neuromuscular capability in youth basketball players are missing in the literature. Nevertheless, there are a few studies examining the effects of simulated match-play on muscular and neuromuscular capability in male youth soccer players and the results of these studies are ambiguous. In some cases leg stiffness was compromised [23,31]; some authors reported a non-significant decrease in ABSLS [24]. In the latter study, the authors also identified that altered stiffness due to simulated match play is individualised (in half of the probands the value increased, in the other half the value decreased).

A comparison of the results of the above mentioned studies suggests that the differences may be influenced by the specifics of fatigue protocols for individual sports (but also within a particular sport), different levels of training of the monitored groups, gender differences, individual responses to the fatigue exercise, etc. Similarly to youth, the results of studies in adult athletes did not bring coherent results. While

leg stiffness decreased after sport-specific fatigue protocol in soccer [22], highly individual changes were reported in runners [37].

Also in the case of reactive strength evaluated by RSI, the results did not show a negative effect of SBFP$_{28}$. In the U16 group, the authors of the present study even recorded a significant improvement in RSI (p = 0.013). The significance of the changes after completing SBFP28 is also confirmed by the "effect size" value (r = 0.53; large effect). The results suggest that the ability to change eccentric muscular action to concentric in a stretch-shortening cycle was not compromised in the players. This indicates that the players demonstrated a good ability of the muscle-tendon unit to cope with the stress induced by SBFP$_{28}$. Considering that jumping and landing are important aspects of basketball-specific fitness and that RSI was determined by means of a drop jump test, it could be expected, that these findings are also positive from the game performance perspective, specifically in terms of the quality of repeated jumping and lending actions. The findings of the current study correspond to the results of a recent study on elite adolescent soccer players (age 15.7 ± 0.5 years), in which RSI increased significantly following a simulated soccer match play [31]. However, in a similar study on elite youth soccer players (age 14.4 ± 0.5 years), RSI decreased significantly.

In the current study, the authors did not observe significant age differences in the fatigue-related responses to SBFP28, either in leg stiffness (ABSLS; RELLS) or RSI. As mentioned above, these results cannot be compared with studies on youth basketball players. Nevertheless, in a later study on youth soccer players aged 13 to 16 years, the authors did not report any significant differences in fatigue-related responses to competitive match play for the parameters observed including ABSLS, RELLS, and RSI between the two age subgroups; 13.6 ± 0.3 years and 15.8 ± 0.1 years. Oppositely, a recent study on female youth soccer players indicated that leg stiffness decreased as a result of post simulated soccer in U13, but did not change in the U15, and increased in the U17 [38].

The data obtained in the present study also indicate that the values of both leg stiffness and RSI were higher in the U18 category compared with U16, in both pre- and post-test. This supports the suggestion that the ability to perform eccentric-concentric movements is positively influenced by age and that the older category has better dynamic stability of the knee joint and consequently a lower risk of ACL injury in sports activities [26,27]. The observed tendency also corresponds to the findings of a later study [25], in which the authors found out a significant increase in leg stiffness between 11 and 20 years of age in boys, with the highest increments between 17 and 20 years.

One of the limitations of the study is that the indicators of neuromuscular fatigue were measured only after the fatigue protocol. Another limitation is a low number of players who were involved in the study.

Conclusion

The SBFP$_{28}$ did not induce a significant reduction either in leg stiffness or reactive strength in the observed group of male adolescent basketball players. The results indicated that irrespective of age, the stabilization function of the knee muscles was not impaired and consequently the risk of ACL injury was not increased. However, a small number of players, and a relatively small age difference and other aspects of the methodological design of the study need to be considered. Due to the lack of similar studies on young

basketball players and the results of a small number of previously conducted studies on youth in other sports, further research into the impact of the acute effect of match simulation protocol or competitive match-play on the mechanisms associated with the risk of ACL injury in youth basketball players is needed.

Conflict of Interest

The authors state no conflict of interest.

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