.

Association between physical fitness and injury patterns in young footballers of the national football development programme in Malaysia

***Muhammad Harith Rosdi[1], Norlaila Azura Kosni[2], Nurul Diyana Sanuddin[2], Zulkhairi Azam[2], Mohd Zairul Faiz Zanudin[3], Veloo Sinnathamby[3], Mohamad Azraie Mohd Faozi[3], Muhammad Amirul Mohd Azmi[3], Muhammad Khairulsyahmi Ahmad Khalidi[3]**

Sri Lanka Journal of Child Health, 2025; **54**(3): 204=211
DOI: http://doi.org/10.4038/sljch.v54i3.11303

Abstract
Introduction: Studies have explored relationship between physical fitness and injury patterns among footballers, but research focusing on young footballers in Malaysia remains limited.

Objectives: To determine associations between physical fitness components (cardiorespiratory fitness, speed, agility and explosive power) and lower limb injury patterns in youth footballers from National Football Development Programme (NFDP) at Akademi Mokhtar Dahari (AMD), Malaysia.

Method: This is a cross-sectional study involving 158 footballers aged 13 to 17 years from AMD. Physical fitness was assessed through VO2max (cardiorespiratory fitness), 5-metre, 10-metre, and 20-metre sprints (speed), arrowhead agility test (agility), and countermovement jump (explosive power). Injuries were categorized into five regions: mid-body, upper-leg, knee, lower-leg, and foot-and-ankle, based on reports by the AMD physiotherapists. Descriptive statistics and k-means clustering were applied to classify players into two groups: best speed-endurance and best power-agility. Chi-square analysis examined injury occurrences.

Results: Players with higher cardiorespiratory fitness had fewer injuries in mid-body but were more prone to knee injuries. Faster players showed increased injury risk across all regions, potentially due to greater acceleration-deceleration forces. Power-agility group exhibited higher risks for knee, foot, and ankle injuries, likely linked to mechanical stress of dynamic movements like jumping and pivoting.

Conclusions: This study highlights potential association with increased injury risks in young players, emphasizing need for balanced training programmes that incorporate neuromuscular control and proprioception.

[1]*Kulliyyah of Medicine, International Islamic University, Malaysia,* [2]*Faculty of Sport Science & Recreation, Universiti Teknologi MARA, Malaysia,* [3]*Akademi Mokhtar Dahari, Malaysia*

**Correspondence:* harithrosdi@iium.edu.my
*https://orcid.org/*0009-0001-7651-5049
(Received on 15 January 2025: Accepted after revision on 21 February 2025)
The authors declare that there are no conflicts of interest
Funding: National Sports Council of Malaysia, provided financial support for study

(Key words: Football, Physical fitness, Injury pattern, Adolescent)

Introduction

Over 240 million are estimated to participate in football globally, including amateur and professional players[1]. Football is a high-intensity team sport involving explosive movements like kicking, tackling, jumping, sprinting, and quickly changing direction. Frequent physical contact and sudden movements, which happen roughly every six seconds, increase risk of injuries[2]. Studies show that physical fitness components like speed, endurance, and agility are key factors in football player recruitment and selection[3]. However, young football players often fall behind elite players in these fitness areas[4]. Research shows that relationship between physical fitness and injury risk is complex[5,6]. Evidence shows that higher fitness levels might increase injury risk because more capable players often experience greater physical demands and longer playing times[7]. In Malaysia, programmes like Akademi Mokhtar Dahari (AMD) are designed to develop future football talent. AMD trains promising young players, aged 13 to 17 years, through intensive programmes that improve skills and physical fitness. However, these demanding programmes can place extra stress on growing bodies, raising risk of injuries. While there is plenty of research on injury rates and fitness in Western countries, there is limited data on Malaysian youth football players.

Objectives

To examine association between physical fitness factors like VO_2 max, agility, speed, and countermovement jump performance with injury risk in young football players.

Method

Participants comprised 158 football players from AMD, ages ranging from 13 to 17 years who were selected as they represent a high-performance group within AMD youth football training programme.

Agility: Arrowhead agility test is a common assessment used to measure an athlete's agility, quickness, and change of direction. The procedure involves marking three cones in a straight line with 5 yards between each cone. Athlete begins at middle cone, sprints to touch one of the outer cones, reverses direction to touch the other outer cone, and finally sprints back through the starting point. Timing starts when the athlete begins movement and stops when he crosses starting cone after completing pattern. Proper footwear and level surface are essential for accuracy and safety during the test[8,9].

Speed:

- *5-metre sprint test* is commonly used to measure an athlete's acceleration and short-distance speed. In this test, participants warm up

.

thoroughly before standing behind starting line. Participants sprint maximally over 5-metre distance on tester's signal, with stopwatch recording their time. Test is usually repeated three times, with rest periods of 2-3 minutes between trials, to ensure accuracy[10].

- *10-metre sprint test* measures an athlete's short-distance acceleration, commonly used in sports requiring rapid bursts of speed. To conduct the test, mark 10-metre distance with the cones on flat, non-slippery surface. After proper warm-up, the athlete starts from standing position and sprints as fast as possible over the distance, with the time recorded using a stopwatch. Test is usually repeated 3-5 times with rest between trials, and the fastest or average time is taken for analysis. Consistency in starting position and equipment setup is key to reliable results[11].
- *20-metre sprint test* is used to measure acceleration and speed over slightly longer distance, often in sports requiring quick bursts of power. Participants begin from the stationary start, sprinting 20 metres as fast as possible while their time is recorded using a stopwatch. Test is typically performed multiple times, with rest between trials, to ensure consistency and reliable results. Surface type, starting stance, and timing equipment should be controlled for accuracy. This test is commonly used in athlete combines and fitness assessments due to its simplicity and effectiveness in measuring explosive power and speed[11].

VO2max test (20 metre shuttle run): Evaluation of maximal aerobic capacity through maximal multistage 20-metre shuttle run test involved participants running between two lines spaced 20 metres apart. A cassette tape emitted tones at specific intervals, dictating pace. Initial speed was set at 8.5 km/hour for the first minute, with subsequent increments of 0.5 km/hour/minute. Participants aimed to reach the line at each tone, and when they could no longer maintain this pace, their participation was concluded. The number of laps completed was recorded[12,13]. Scores from the final stage were converted to predict maximal oxygen uptake (VO2 max), expressed in ml of oxygen consumed/kg body weight/minute. Maximal aerobic speed (MAS) corresponds to lowest speed enabling attainment of VO2 max, representing level of maximum aerobic capacity for subject. Throughout test, participants received verbal encouragement to run for as long as possible. This comprehensive approach allowed a thorough assessment of the aerobic capacity and provided valuable data for predicting VO2 max based on performance in the shuttle run test[14,15].

Counter-movement jump (CMJ) test: This is an effective method for assessing an athlete's explosive lower-body power and neuromuscular function. To conduct the test, participants begin by performing proper warm-up consisting of light aerobic exercises and dynamic stretches. Once prepared, athlete stands on a force plate or a jump mat with feet shoulder-width apart, and then executes a quick downward squat before immediately jumping upwards as high as possible without pausing at the bottom of the movement. Jump height can be measured using the force plate, which captures flight time, or through the jump mat that automatically records the vertical jump height. It is recommended that the athlete completes 3-5 trials, allowing 1-2 minutes of rest between jumps to prevent fatigue, with the highest jump recorded for analysis. Safety measures should be taken to ensure that a non-slippery surface is used and that the athlete is adequately warmed up to minimize risk of injury[16].

Injury recording: Categorization of the injuries was conducted systematically using data obtained from injury reports provided by AMD physiotherapists. These reports included detailed descriptions of the nature, severity, and location of each injury. Authors developed standardized framework to classify injuries, ensuring consistency and comparability across all the recorded cases. This categorization process was informed by current best practices in sports medicine and aligned with established injury classification guidelines. Any ambiguities in injury descriptions were resolved through consultations with the reporting physiotherapists to maintain accuracy and reliability in the dataset.

Ethical issues: Study approval was obtained from IIUM Research Ethics Committee, Malaysia (No. IIUM/504/14/11/2/ IREC 2023-162) on 04.10.2023. Written informed consent was obtained from parents/guardian of participants and assent from participants.

Statistical analysis: The k-means clustering algorithm was used to separate classes of related performance variables assessed using SPSS version 29. It is reported that the k-means clustering method is more reliable than hierarchical agglomerative because it operates on actual observations rather than dissimilarity measures employed in hierarchical clustering. Number of clusters, k is selected to be 2 as the data consist of best and moderate performance based on 4 physical performances namely, endurance, speed, agility and explosive power. Chi-square test is primarily designed to aid study of categorical data. On the other hand, Chi-square test considers counted and classified dataset and will not operate with numeric data that are parametric or continuous. Chi-square analysis is used in the current study to examine the status of soccer-related injuries as reported by the medical team.

Results

Five categories of body region were introduced to split injury cases (Table 1).

Table 1: *Injury area*

No.	Body region	Body part (Case)	Cases
1	*Mid body*	Pelvis, lip and groin	26
2	*Upper leg*	Upper leg	24
3	*Knee*	Knee	35
4	*Lower leg*	Lower leg	18
5	*Foot and ankle*	Ankle (37), heel and Achilles tendon (1), foot and toes (17)	55

.

The five fitness performances were recorded and k-means clustering technique was used to group players according to fitness performance. The two best groups were speed-endurance and best power-agility (Table 2).

Table 2: *Grouping based on best physical fitness components*

Group	VO2MAX	Speed	Agility	CMJ
1. (Power-agility)	48.81 (1.85) Moderate	6.11 (0.21) Moderate	16.06 (0.30) Best	47.25 (3.64) Best
2. (Speed-endurance)	54.27 (1.75) Best	5.54 (0.13) Best	17.06 (0.36) Moderate	35.73 (3.34) Moderate

VO₂ max table categorizes participants into various groups, with the corresponding average VO_2max values. VO_2max, a key indicator of cardiovascular fitness, ranges from approximately 48.72 for the "moderate" group to a higher average of 54.31 for the "best" group, signifying superior aerobic capacity (Figure 1).

Figure 1: *VO2 Max table*

Chi square test examined relationship between the injury risk and the endurance performance and found it statistically significant, χ^2 (4, N = 121) = 10.33, p = 0.035. Thus, one can reject the null hypothesis and consider that there is a significant relationship between the injury risk and the endurance performance (Table 3).

Table 3: ***Chi-Square test of injury risk and endurance performance***

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-square	10.325[a]	4	0.035
Likelihood ratio	10.637	4	0.031
Linear-by-Linear association	2.033	1	0.154
No. of valid cases	121		

a: 0 cells (0%) have expected count less than 5. The minimum expected count is 5.16.

Speed table highlights average speed performance across similar categories. The "best" group recorded the fastest average speed at approximately 5.54 seconds while the "moderate" group exhibited slower speeds, averaging around 6.13 seconds. This reflects variations in speed performance across categories (Figure 2).

Figure 2: *Speed table*

.

Chi square test examined the relationship between the injury risk and the speed performance and found it statistically significant, χ^2 (4, n = 93) = 9.67, p = 0.046 (Table 4). Thus, one can reject the null hypothesis and consider that there is a significant relationship between injury risk and speed performance.

Table 4: ***Chi-Square test of injury risk and speed performance***

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-square	9.668[a]	4	0.046
Likelihood ratio	9.595	4	0.048
Linear-by-Linear association	.083	1	0.774
No. of valid cases	93		

a: 1 cell (10%) has expected count less than 5. The minimum expected count is 3.76.

In the **Agility** table, average agility values are presented for each group. Agility scores range from 16.02 seconds for the "best" group, indicating high agility, to approximately 16.96 seconds for the "moderate" group, suggesting a relatively lower agility performance (Figure 3).

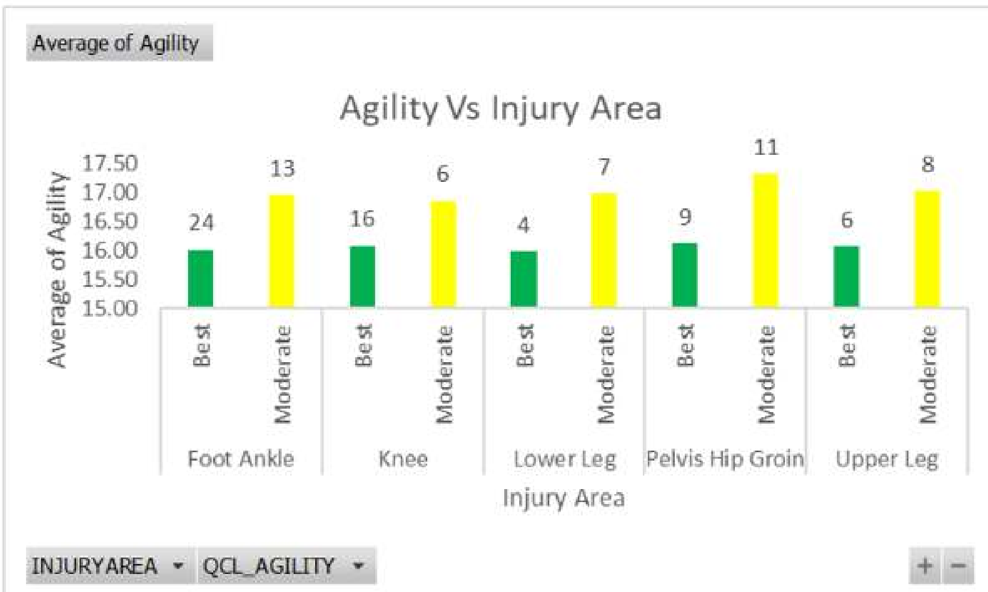

Figure 3: ***Agility table***

Chi square test examined the relationship between the injury risk and the agility performance and found it statistically not significant, χ^2 (4, N = 104) = 7.37, p = 0.118 (Table 5). Thus, one can accept the null hypothesis and consider that there is no significant relationship between the injury risk and agility performance.

Table 5: ***Chi-Square test of injury risk and agility performance***

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-square	7.369[a]	4	0.118
Likelihood ratio	7.462	4	0.113
Linear-by-Linear association	1.795	1	0.180
No. of valid cases	104		

a: 1 cell (10%) has expected count less than 5. The minimum expected count is 4.76.

The CMJ table focuses on the countermovement jump performance. The "best" group achieved the highest average jump height of 48.01cm, whereas the "moderate" group had a significantly lower average of 35.39cm. This suggests a stark difference in explosive power and jump performance among categories (Figure 4).

.

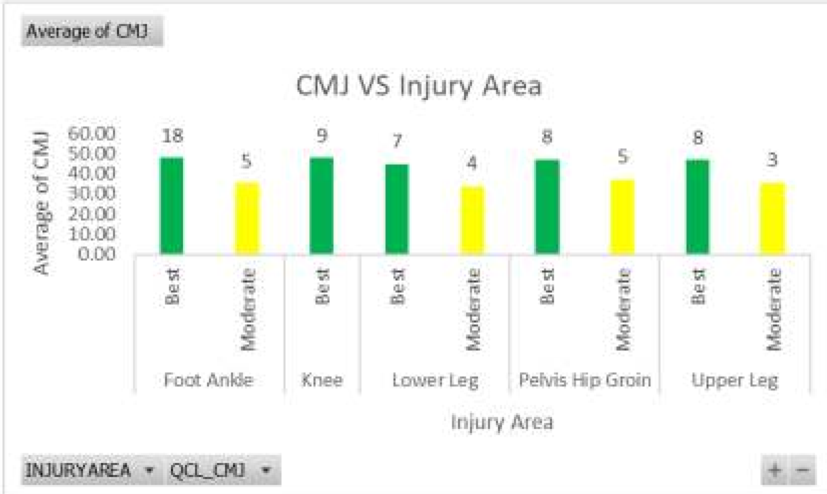

Figure 4: ***Countermovement Jump (CMJ) table***

Chi square test examined the relationship between the injury risk and explosive power. Relationship between the injury risk and explosive power was statistically not significant, χ^2 (4, N = 64) = 7.34, p = 0.12 (Table 6). Thus, one can accept the null hypothesis and consider that there is no significant relationship between the injury risk and explosive power.

Table 7 shows the correlations of Spearman's Rho between physical fitness and the injury area.

Table 6: ***Chi-Square test of injury risk and explosive power***

	Value	df	Asymptotic significance (2-sided)
Pearson Chi-square	5.609[a]	4	0.230
Likelihood ratio	7.337	4	0.119
Linear-by-Linear association	.248	1	0.618
No. of valid cases	64	4	0.12

a: 4 cells (40%) have expected count less than 5. The minimum expected count is 1.97.

Table 7: ***Correlations of Spearman's Rho between physical fitness and injury area***

Correlations: Spearman's Rho		Injury area
VO_{2MAX}	Correlation Coefficient	0.129
	Sig. (2-tailed)	0.159
	N	121
5 Metre	Correlation Coefficient	0.070
	Sig. (2-tailed)	0.503
	N	94
10 Metre	Correlation Coefficient	0.013
	Sig. (2-tailed)	0.904
	N	94
20 Metre	Correlation Coefficient	0.025
	Sig. (2-tailed)	0.816
	N	93
Agi R	Correlation Coefficient	-0.112
	Sig. (2-tailed)	0.260
	N	104
Agi L	Correlation Coefficient	-0.135
	Sig. (2-tailed)	0.171
	N	104
CMJ	Correlation Coefficient	-0.058
	Sig. (2-tailed)	0.648
	N	64

Spearman coefficient ranges from –1 to +1. It can be interpreted as describing anything between no association (ρ = 0) to perfect monotonic relationship (ρ = –1 or +1). Analogous considerations described for the Pearson correlation also apply to interpretation of confidence intervals and p values for Spearman coefficient.

.

In the current study, there is negligible strength shown between the physical performance and the injury area. Result indicates that injury has poor relationship with physical performance.

Discussion

This study explored how different physical fitness components correlate with risk of lower limb injuries among young footballers aged 13 to 17 years in Malaysia. Our results showed a higher risk of lower limb injuries in footballers with better physical fitness components. Although differences were not statistically significant, they offer valuable insights into the potential factors influencing injury risk in young athletes.

Firstly, we found that players with better cardiorespiratory fitness (CRF) had fewer injuries in upper parts of lower limb—pelvis, hip, groin, and thigh. This suggests that good aerobic capacity might protect against injuries in these areas by increasing muscle endurance and delaying muscle fatigue, known to impair muscle function and coordination. Prolonged matches or intense training sessions without adequate rest may lead to fatigue-related impairments including poor muscle coordination leading to improper joint loading[17]. Better CRF leads to better oxygen delivery to muscles, improves recovery and reduces risk of muscle strain in areas such as hamstring and groin, the dominant muscles in football. Interestingly, these same players showed higher risk of knee injuries compared to those with lower CRF. One possible explanation is that fitter footballers tend to play longer and at higher intensities, placing more repetitive stress on the knee joint. Unfortunately, as our study did not explore playing time, no conclusion could be made.

Secondly, footballers with better speed, measured through 5-metre, 10-metre, and 20-metre sprints, had higher risk of injuries across all parts of lower limbs. This concurs with a study in 2022 where faster junior Australian football players experienced higher injury incidence, which may be explained by faster players experiencing greater acceleration and deceleration forces during match play, thus increasing the load on the musculoskeletal system[18]. Wide midfielders and strikers typically exhibit superior sprinting performance, including higher sprint distances and peak velocities[19]. They engage in significantly more high-intensity running and sprinting compared to other positions due to their offensive roles and their frequent involvement in transitions and counterattacks[20]. They frequently engage in explosive actions like sudden stops and quick changes in direction, heightening the risk of strains and sprains. Thus, they are exposed to greater risk for injuries. Faster players also generate higher forces upon sprinting, leading to higher stress on muscles, tendons, and joints. This is particularly concerning during deceleration, as braking forces during rapid stops can exceed three times body weight and are concentrated in areas like knee and ankle[21]. Moreover, adolescents may not have fully developed their neuromuscular control to handle high-speed movements safely, making them more susceptible to injuries[22].

Thirdly, the group with higher power and agility had a higher risk of injuries to knee, foot, and ankle compared to the speed-endurance group. Power and agility involve explosive strength and rapid directional changes, demanding significant effort from the musculoskeletal system. Dynamic movements like jumping, cutting, and pivoting impose substantial loads on joints and soft tissue, which, if not managed with proper technique and conditioning, may increase the risk of injuries especially at the distal part of the lower limbs. Our finding of higher injury risk in better agility groups concurs with a study on Australian rugby players which found that rugby players with poorer agility had lower risk of injury. The results were surprising, as they originally hypothesized that agility would be protective against lower limb injuries. Their explanation was that players with poorer agility and reaction times move slower during pivoting and changing directions, reducing the risk of pivoting injuries over knee and ankle joints[23].

Furthermore, players with better explosive power, assessed by better CMJ, exhibited a higher risk of injuries in all areas of lower limbs, which concurs with a study on elite youth volleyball players which reported better CMJ in players with jumper's knee compared to the non-injured group. An explanation could be that the players who jump higher subject their tendons to a higher load and therefore have a higher risk of overuse injuries[24]. Another explanation is that explosive movements generate high mechanical loads that may exceed the capacity of developing musculoskeletal structures in adolescents, making them more prone to overuse injuries.

Similar observations, where better physical performance leads to a higher injury risk, have been reported in other sports. In baseball, pitchers with the fastest throws seem to have a higher risk of overuse injuries to shoulder and elbow. As they performed better, they played more months per year, games per year and pitches per game[25]. Similar to Australian cricket, faster throwers played more games resulting in significantly higher risk of injury[26]. Ideally, we wanted to include physical fitness components, match exposure and training exposure in one multivariate model but this was not possible, as we have no data on training and match exposure.

These findings highlight the need for training programmes to focus on the specific needs of adolescent athletes. A well-balanced programme combining flexibility, balance, neuromuscular control, and proprioceptive training is more effective at reducing the injury risk than focusing on individual physical fitness components alone. Fitter and faster players are important for better team performance, but coaches must carefully monitor training loads and make sure the players get enough recovery time. Educating players on safe techniques and encouraging them to report any discomfort can help prevent injuries.

Studies with larger samples are needed to verify these findings and explore them in greater depth. Longitudinal studies tracking players over several seasons could provide valuable insights into how growth and training interact to influence injury risk. Other physical attributes such as neuromuscular control may provide better correlation with injury risk in adolescent football. Additionally, match and training exposure should be included and analysed to give better insight on injury risk.

Conclusions

Our study suggests that in adolescent footballers, greater speed, power, and agility might increase the risk of lower limb injuries.

.

Acknowledgement
This research was funded by the National Sports Council of Malaysia, which provided financial support for the study.

References

1. Bujnovky D, Maly T, Ford K, Sugimoto D, Kunzmann E, Hank M, *et al.* Physical fitness characteristics of high-level youth football players: Influence of playing position. *Sports* 2019; **7**(2): 46. https://doi.org/10.3390/sports7020046 PMid: 30781535 PMCid: PMC6409586
2. Bjordal JM, Arnøy F, Hannestad B, Strand T. Epidemiology of anterior cruciate ligament injuries in Soccer. *American Journal of Sports Medicine* 1997; **25**(3): 341–5. https://doi.org/10.1177/036354659702500312 PMid: 9167814
3. Jaleel A, Hadi AK, Saad AK. Predictive value of skill performance in terms of physical indicators in 14-year-old football players. Sport TK-*Revista EuroAmericana de Ciencias del Deporte* 2022 **11**(Suppl 2). https://doi.org/10.6018/sportk.526811
4. Priya S, Umananda M, Devika K. Relationship between explosive strength and agility among college level football players: A pilot study. *Indian Journal of Physical Therapy and Research* 2021; **3**(1): 8. https://doi.org/10.4103/ijptr.ijptr_29_20
5. Farley JB, Barrett LM, Keogh JWL, Woods CT, Milne N. The relationship between physical fitness attributes and sports injury in female, team ball sport players: a systematic review. *Sports Medicine - Open* 2020; **6**(1). https://doi.org/10.1186/s40798-02000264-9 PMid: 32926228 PMCid: PMC7490320
6. Farley JB, O'Hara M, Justin, Woods CT, Rathbone E, Milne N. Relationships between physical fitness characteristics, technical skill attributes, and sports injury in female Australian football players. *PloS One* 2024; **19**(2): e0298267. https://doi.org/10.1371/journal.pone.0298267 PMid: 38386636 PMCid: PMC10883547
7. Macmillan C, Olivier B, Benjamin-Damons N, Macmillan G. The association between physical fitness parameters and in-season injury among adult male rugby players: a systematic review. *Journal of Sports Medicine and Physical Fitness* 2022; **62**(10):1345–58. https://doi.org/10.23736/S00224707.21.13171-8 PMid: 34931786
8. Bompa TO, Sarandan S. Training and conditioning young athletes. Human Kinetics; 2022. https://doi.org/10.5040/9781718241077
9. Bompa TO, Buzzichelli C. Periodization: theory and methodology of training. 6th ed. Champaign, Il: Human Kinetics; 2019. https://doi.org/10.5040/9781718225435
10. Sporis G, Ruzic L, Leko G. The anaerobic endurance of elite soccer players improved after a high-intensity training intervention in the 8-week conditioning programme. *Journal of Strength and Conditioning Research* 2008; **22**(2): 559-66. https://doi.org/10.1519/JSC.0b013e3181660401 PMid: 18550974
11. Hetzler RK, Stickley CD, Lundquist KM, Kimura IF. Reliability and accuracy of handheld stopwatches compared with electronic timing in measuring sprint performance. *Journal of Strength and Conditioning Research* 2008; **22**(6):1969-76. https://doi.org/10.1519/JSC.0b013e318185f36c PMid: 18978613
12. Léger LA, Lambert J. A maximal multistage 20-m shuttle run test to predict VO2 max. *European Journal of Applied Physiology and Occupational Physiology* 1982; **49**(1):1-12. https://doi.org/10.1007/BF00428958 PMid: 7201922
13. Vanhelst J, Le Cunuder A, Léger L, Duclos M, Mercier D, Carré F. Sport participation, weight status, and physical fitness in French adolescents. *European Journal of Pediatrics* 2024; **183**(12): 5213-21. https://doi.org/10.1007/s00431-02405796-w PMid: 39354223
14. Muazu Musa R, Razali Abdullah M, Bisyri Husin Musawi Maliki A, Azura Kosni N, Haque M. The application of principal components analysis to recognize essential physical fitness components among youth development archers of Terengganu, Malaysia. *Indian Journal of Science and Technology* 2016; **9**(44): 1-6. https://doi.org/10.17485/ijst/2016/v9i44/97045
15. Gathercole R, Sporer B, Stellingwerff T, Sleivert G. Alternative countermovement-jump analysis to quantify acute neuromuscular fatigue. *International Journal of Sports Physiology and Performance* 2015; **10**(1): 84-92. https://doi.org/10.1123/ijspp.2013-0413 PMid: 24912201
16. Anicic Z, Janicijevic D, Knezevic OM, *et al.* Assessment of countermovement jump: What should we report? *Life (Basel)* 2023; **13**(1): 190. https://doi.org/10.3390/life13010190 PMid: 36676138 PMCid: PMC9865236
17. Kakavas G, Malliaropoulos N, Gabbett T, Mitrotasios M, Dyk N, Bikos G, Maffulli N. A 90-minute soccer match induces eccentric hamstring muscles fatigue. *Muscles, Ligaments and Tendons Journal* 2021; **11**: 318-23. https://doi.org/10.32098/mltj.02.2021.15
18. Bennett H, Chalmers S, Arnold J, *et al.* The relationship between performance and injury in junior Australian football athletes. *International Journal of Sports Physiology and Performance* 2022; **17**(5): 761-7. https://doi.org/10.1123/ijspp.2021-0308 PMid: 35226865
19. Oliva-Lozano JM, Fortes V, Krustrup P, Muyor JM. Acceleration and sprint profiles of professional male football players in relation to playing position. Harnish C, editor. *PLOS One* 2020; **15**(8): e0236959.

.

https://doi.org/10.1371/journal.pone.0236959 PMid: 32760122 PMCid: PMC7410317

20. Di Salvo V, Baron R, González-Haro C, Gormasz C, Pigozzi F, Bachl N. Sprinting analysis of elite soccer players during European Champions League and UEFA Cup matches. *Journal of Sports Sciences* 2010; **28**(14): 1489–94. https://doi.org/10.1080/02640414.2010.521166 PMid: 21049314
21. Petersen J, Nielsen RO, Rasmussen S, Sørensen H. Comparisons of increases in knee and ankle joint moments following an increase in running speed from 8 to 12 to 16km·h−1. *Clinical Biomechanics* 2014; **29**(9): 959–64. https://doi.org/10.1016/j.clinbiomech.2014.09.003 PMid: 25242200
22. QuatmanYates CC, Quatman CE, Meszaros AJ, *et al.* A systematic review of sensorimotor function during adolescence: a developmental stage of increased motor awkwardness? *British Journal of Sports Medicine* 2012; **46:** 649-55. https://doi.org/10.1136/bjsm.2010.079616 PMid: 21459874 PMCid: PMC4157222
23. Gabbett TJ, Ullah S, Jenkins D, Abernethy B. Skill qualities as risk factors for contact injury in professional rugby league players. *Journal of Sports Sciences* 2012; **30**(13): 1421–7. https://doi.org/10.1080/02640414.2012.710760 PMid: 22845418
24. Visnes H, Aandahl HÅ, Bahr R. Jumper's knee paradox—jumping ability is a risk factor for developing jumper's knee: a 5-year prospective study. *British Journal of Sports Medicine* 2013; **47:** 503-7. https://doi.org/10.1136/bjsports-2012-091385 PMid: 23060653
25. Olsen SJ, Fleisig GS, Dun S, Loftice J, Andrews JR. Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. *American Journal of Sports Medicine* 2006; **34**(6): 905-12. https://doi.org/10.1177/0363546505284188 PMid: 16452269
26. Saw R, Dennis RJ, Bentley D, *et al.* Throwing workload and injury risk in elite cricketers. *British Journal of Sports Medicine* 2011; **45:** 805-8. https://doi.org/10.1136/bjsm.2009.061309 PMid: 19622529