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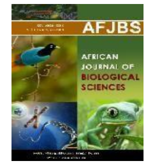

Effect of Fatigue on Core Endurance, Balance and Performance in Adolescent Football Players

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Abstract:
Background: the volume of research that has studied the fatiguing effects on postural control is high, while studying the fatigue effect on balance and actual sport performance in football players has been of less attention.
Objectives: to examine the impact of fatigue on core endurance and balance in addition to performance in adolescent football players**.**
Subjects and methods: 60 male football players were randomized into one of two groups: one fatigue group, and the control group. Initially, all players were evaluated for core endurance, balance, as well as performance. After that, the fatigue group was given a fatigue protocol to follow. After that, all measurements were repeated.
Study design: Randomized clinical study.**Results:**Within group comparison there was a significant difference between pre and post measurements for all variables of the fatigue group,while in the control group there was a non-significant difference between pre and post measurements of all variables.Between groupscomparison there was a non-significant difference of all outcome measures betweengroups in pre fatigue measurements,while post fatigue protocol there was a significant difference regarding balance and running sprint time and non-significant differenceregarding core endurance and Triple-Hop Test.
Conclusion: Fatiguehas a negative impact on adolescent football player'sbalanceand performance that could increase the risk of injury.
Key words: fatigue, core endurance, balance, performance, football.

INTRODUCTION

Football is the most popular sport in the world. Nearly 4.1% of people play football regularly globally, males making up the majority of participants (nearly 90%) **(Krishna et al., 2020)**.Players tackle, kick, jump, dribble, and head balls during a match, usually with a change of activity every 4–6 seconds **(Jadczak et al., 2019)**, Therefore it is a highly coordinated and complex sport in which aerobics and anaerobic performance are used together **(Dupont et al., 2010; Müniroğlu&Deliceoğlu, 2008).**

In elite football, one to three matches can be played over a seven-day period**(Dragoo& Braun, 2010).** The strain that football players are exposed to in training and competition can cause metabolic, neuromuscular, and mental fatigue which has a negative impact on performance and increases the risk of injury **(Fessi et al., 2016;Meyer et al., 2013).** Among football players poor control of training load and muscular fatigue are the biggest risk factors for non-contact injuries**(Soligard et al., 2016).**Fatigue is a temporary, exercise-induced reduction in baseline and pre-match physiological as well as psychological functioning that impacts the musculoskeletal along with neurological systems **(Knicker et al., 2011; Enoka &Duchateau., 2008).**Football is a game of fast and varied movements therefore maintaining the dynamic balance is essential**(Krishna et al., 2020),**The deteriorations in balance and performance occurs after 20-minute of activity**(Ishızuka et al., 2011).**Generally, the volume of research that has studied the fatiguing effects on postural control is high, but studying its effect on balance and sport performance in football players has been of less attention**(Farzami&Anbarian 2020; Güleret al.,2020; Zago et al., 2021).**

Balance is a complex process that needs precise synchronization of the central nervous system and the limbs, maintaining balance is essential for football players when they come down from a heading opportunity and touch the ball with one foot **(Yaggie& McGregor, 2002).** Few studies have examined the relationship between balance and functional performance despite the fact that it is essential for successful football performance, particularly among young athletes **(Pau,Ibba, &Attene, 2014; Pollock., 2010).Paillard et al. (2006) and Aytar et al. (2012)**have identified that the balance and Core stabilityare important aspects of the football players performance, On the other hand, postural sway becomes more pronounced as a result of fatigue-induced loss of balance **(PauIbba, &Attene, 2014)** and the relationship between these components is not fully understood**(Aytar et al., 2012).**

The current study applied fatigue protocol that would reflect the complexity that mimic the physical fatigue which occurs during an actual game to provide a clearer picture of the effects of football-specific fatigue on core endurance, balance, and performance in adolescent football players.

METHODS

Participants

A total of sixty male football players from Wadi-Degla (2005, 2006 and 2007) football teams. The players were randomized to be in the control group or the fatigue group. The use of computer-generated random numbers has been employed for randomizations.This study was conducted at Wadi-Degla football club,Egypt. All participants received medical clearance prior to participating in the study, and they were all in perfect health when the data was collected. The study data were collected at the end of the season in July 2023. With five training days and one normal league match each week, every player was under an identical training regime. Participants were not allowed to participate if they had a history of musculoskeletal injuries at least one year before the protocol was implemented. The informed consent form was signed by all participants before the trial. Ethical review by the faculty of physical therapy at Cairo University gave their approval to the study protocol (NCT06069635), and it was also included in the clinical trial registration website.

Randomization

After screening the inclusion and exclusion criteria, eligible players were informed about the aim of the study and all testing procedures. Players were randomized into either fatigue or control group using computer - generated random number with 30 players in each group.

Outcome Measures

The primary outcome measurecore endurance testing by the following tests: trunk flexion test (McGill's test), trunk extension (Sorenson Test)**,** side plank test as well as prone plank test**.** The test's strong validity for measuring core muscular endurance and excellent reliability (ICC = 0.99) led to its selection **(Saporito et al., 2015).**

- **Trunk flexion test (McGill's test):**

The athlete was positioned in a sit-up position, with their back at a position that was sixty degrees from the floor. In this position, you should bend at the knees and hips 90 degrees, cross your arms over your chest, and rest one hand on your other shoulder. Make sure to hold onto your feet at all times. Theplayer holds the isometric posture as long as possible. Failure is determined when any part of the player's back moved backward. Time the player can hold the isometric posture was recorded**(Brumitt et al. 2013).**

- **Trunk extension (Sorenson Test):**

After securing the pelvis, knees, and hips, the upper body was elevated off a bench to test the back extensors, specifically the multifidus and erector spinae. With the hands lying on the opposite shoulders, the upper limbs are held across the chest. When the top half of the body stops being horizontal, failure happens. The time recorded as long asthe player could hold his body straight**(Brumitt et al. 2013).**

- **Side plank test:**

The test started with player lying on the side then the therapist asked him to lift the body on the elbow, forearm, and feet stacked creating a straight line from head to toe. The time recorded if he could hold his body and hip off the floor**(Brumitt et al. 2013).**

- **Prone plank test:**

The player asked to lie in a prone position, support the upper body off the ground with the elbows and forearms, as well as to take the weight by the toes with the legs straight. The body forms a straight line from the head to the toes when the hip is raised off the floor. Instead of looking ahead, the head should be pointing towards the ground. Time was recordedand the test is over when the player is unable to hold the back straight and the hip is lowered**(Tong et al., 2014).**

The secondary outcome measures included Balance assessment, which was assessed bythe "MFT Challenge Disc®"The MFT software is attached to a rubber buffer linkage that holds a 530 mm diameter circular plate (Trend Sport Trading GmbH, Großhofein, Austria). The platform's tilt sensor records movement in any direction **(Raschner, 2008).**

This device quantifies the dynamic and staticbalancing abilities of individuals on an instable surface with a valid and reliable data.**(Pojskic et., al 2020and und Schülern S 2012).**MFT Challenge Discused to assess dominant (D) and non-dominant (N) single-leg balance test (SLBT-D, SLBT-N). The player was told to stand completely still while keeping the balance platform horizontal. The player is instructed to maintain a straight line of vision while all visual feedback about their performance is hidden during the testing. During the test, one leg was elevated off the ground and the other leg was bent at the knee joint; the foot of the standing leg was put on the balancing plate with a slight flexion in the knee.Throughout the tests, the player kepthis hands on his waist; if he madetwo mistakes within the trial a second trial would be allowed. Over the course of a 20-second trial, the system tracks the participant's stability index by observing plate movement and deviations from the horizontal plane. On a scale from 1 to 5, the stability index score indicates the degree of stability, with lower scores indicating less deviation.**(Pojskic et al., 2020).**

The third outcome measures included the player Performance which wasassessed using the 20-m running sprint as well as Triple-Hop Test (THT):

- **The 20-m running sprinttest:**

Two trials of maximal sprints of 20 mwereperformed, with 3 min of rest between each trial; following a two warm-up trials; the time taken was recorded using a stop watch; only the fastest trials were included in the final analysis**(Cressey, West, Tiberio, Kraemer, &Maresh, 2007).**The 20-m running test is a highly reproducible and was able to track aerobic fitness changes in well-trained players**(Paradisis et al., 2014,Aziz AR 2005 and Hopker JG, 2009).**

- **Triple-Hop Test (THT):**

The playerwas instructed to stand in a stepping position andhopthree times on the dominant leg to reach the maximal horizontal distance. Measurement taken from the starting line to the point where the heel struck the ground the test repeated three times and the best score was recorded in centimeters **(Rambaud et al.,2020).**This test is a valid test which is widely used to measure aerobic fitness and performance**(Lloyd RS.et al.,2020 and Paradisis et al., 2014).**

- **The Fatigue protocol repeated sprint ability (RSA)**:

Recognized as a valid method for simulating football players' fatigue and performance decline **(Bangsbo, Mohr, &Krustrup, 2006).**The design of the RSA protocol is based on the intermittent nature and high-intensity actions of football**,**Results on this RSA test is significantly correlated with the distances that professional football players cover running during official matches**(Calderón-Pellegrino, Gabriel, et al., 2020)**

In a prior study, **Buchheit et al. (2010)** used the RSA procedure on athletes of the same age. The protocol was carried out on a synthetic grass field and consisted of six sets of maximal 215m shuttle sprints, with each set consisting of five meters in one direction and five meters in the other. Every set was separated by twenty seconds of passive recovery, which included slow walking, deceleration, and getting ready for the next test. Every player must complete a short, 20-minute standardized warm-up before beginning the RSA protocol. The warm-up included a 6-minute run at an incremental speed from 60% to 80% of one's maximal aerobic speed as well as a 6-minute stretch. Next, two minutes of submaximal speed shuttle sprints were performed, followed by forty seconds of passive recovery. After that, two minutes of submaximal speed RSA protocol simulation were performed (two repetitions), and this was again subsequently followed by forty seconds of passive recovery. Finally, two minutes of forward, backward, and lateral jogging as well as high-knee and "butt-kick" runs were completed **(Pau, Ibba, &Attene, 2014).**

The following is the formula for the fatigue index (FI), which is a measure of RSA performance expressed as a percentage decrement score:FI = [100x (Total sprint time / Ideal sprint time)] - 100Total sprint time represents the total time of six 30 meters maximalsprints as well as theIdeal sprint time is the time of fastest one.The players promptly committed themselves to conducting all measurements without delay, ensuring that no more than 20 seconds elapsed between the completion of the last sprint and the commencement of the measurements. This was done to prevent any masking effects associated with the gradual recovery from fatigue**(Pau, Ibba, &Attene, 2014).**

Data analysis

An independent t-test was used to compare the characteristics of players among groups. The Shapiro-Wilk test was used to ensure that the data followed a normal distribution. A Levene's test was performed to assess the homogeneity among groups. A MANOVA analysis was used to examine the impact of fatigue on core endurance, balance, as well as player performance. Post-hoc tests were conducted utilizing the Bonferroni correction to compare multiple groups. The statistical tests were conducted with a predetermined level of significance of $p < 0.05$. The statistical analysis was performed using the SPSS software package, specifically version 25 for Windows, developed by IBM SPSS in Chicago, IL, USA.

RESULTS

No playerdiscontinued the research project for any reason. No side effects or complications were observed during the study.

Player'scharacteristics:

Table (1) reveals the characteristics of the players in both the fatigue as well as control groups. no statistically significant difference was found among the groups in terms of age and BMI ($p > 0.05$).

Table1. Comparison of subject characteristics among the fatigue and control groups:

	igue group	**ıtrol group**				**ıificance**
	an ±SD	an ±SD	)	alue	alue	
: (years)	·97 ± 0.89	′3 ± 0.58	4	)	3	
II (kg/m²)	·58 ± 0.31	′3 ± 0.31	)5	·3	3	

SD, standard deviation; MD, mean difference; p value, probability value; NS, no significant change

Effect of fatigue on core endurance, balance and performance:

Within group comparison: a significant decline in endurance in trunk flexion, side plank and prone plank tests ($p < 0.001$). On the contrary,there was no significant change in trunk extensiontest post- fatigue compared with that pre fatigue in fatigue group. While there were no significant changes in trunk flexion test, side plank test as well as prone plank test and trunk extension test in the control group ($p > 0.05$) **(Table 2).**

There was a significant increase in SLBT-D, SLBT-ND, 20-m running sprint time and a significant decrease in THT post fatigue compared with that pre fatigue in fatigue group ($p < 0.001$) while there were no significant changes in the control group ($p > 0.05$). **(Table 3).**

Between group comparison

There was no statistically significant difference among the groups before fatigue ($p > 0.05$). There was no statistically significant difference in trunk flexion test, trunk extension test, side plank test, prone plank test, as well as THT between the groups after the fatigue protocol ($p > 0.05$). There was a significant increase in SLBT-D, SLBT-ND and 20-m running sprint test post fatigue of fatigue group compared with that of control group ($p < 0.01$). **(Tables 2-3).**

Table 2. Mean trunk flexion test, trunk extension test, side plank test, prone plank test before and after fatigue of the fatigue and control groups:

	Pre fatigue	Post fatigue			
	Mean ±SD	Mean ±SD	MD	of change	ɔ value
Trunk flexion					
Fatigue group	99.9 ± 42.91	94.63 ± 42.91	5.27	5.28	0.001
Control group	102.57 ± 46.19	101.74 ± 46.16	0.83	0.81	0.15
MD	-2.67	-7.11			
	p = 0.81	*p = 0.54*			
Trunk extension					
Fatigue group	106.33 ± 39.25	106.27 ± 38.64	0.06	0.06	0.97
Control group	112.43 ± 37.73	110.85 ± 38.09	1.58	1.41	0.38
MD	-6.1	-4.58			
	p = 0.54	*p = 0.64*			
Side plank					
Fatigue group	69.13 ± 13.12	65.30 ± 12.14	3.83	5.54	0.001
Control group	69.33 ± 12.89	68.33 ± 13.31	1	1.44	0.11
MD	-0.2	-3.03			
	p = 0.95	*p = 0.36*			
Prone plank					
Fatigue group	92.53 ± 26.57	88.33 ± 26.68	4.2	4.54	0.001
Control group	93.53 ± 26.52	92.27 ± 27.05	1.26	1.35	0.11
MD	-1	-3.94			
	p = 0.88	*p = 0.57*			

SD, standard deviation; MD, mean difference; p value, probability value

Table 3. Mean SLBT, 20-m running sprint and THT pre and post fatigue of fatigue and control groups:

Endurance (sec)	Pre fatigue	Post fatigue			
	Mean ±SD	Mean ±SD	MD	of change	ɔ value
SLBT-D					
Fatigue group	4.17 ± 0.32	4.38 ± 0.26	-0.21	5.04	0.001
Control group	4.12 ± 0.29	4.13 ± 0.32	-0.01	0.24	0.58
MD	0.05	0.25			
	p = 0.56	*p = 0.001*			
SLBT-ND					
Fatigue group	4.61 ± 0.23	4.75 ± 0.19	-0.14	3.04	0.001
Control group	4.58 ± 0.24	4.59 ± 0.23	-0.01	0.22	0.67
MD	0.03	0.16			
	p = 0.65	*p = 0.005*			
20-m running sprint (sec)					
Fatigue group	157.07 ± 35.34	182.37 ± 30.99	-25.3	16.11	0.001
Control group	158.87 ± 38.14	159.30 ± 34.97	-0.43	0.27	0.87
MD	-1.8	23.07			
	p = 0.85	*p = 0.009*			

THT (cm)					
Fatigue group	502.13 ± 13.81	499.37 ± 13.72	2.76	0.55	0.001
Control group	502.37 ± 12.93	501.47 ± 13.25	0.9	0.18	0.13
MD	-0.24	-2.1			
	p = 0.94	*p = 0.54*			

SD, standard deviation; MD, mean difference; p value, probability value; SLBT-D, single-leg balance test of dominant limb; SLBT-ND; single-leg balance test of non- dominant limb

DISCUSSION

Results of the current study showed negative impacts of fatigue on players' performance in trunk endurance tests. Likewise, a reduction in balance and functional performance was observed following fatigue.

Decrement of hold time in trunk flexion, side plank, and prone plank endurance tests after application of fatigue protocol comes in agreement with **Hajmirzaei et al. (2023),**according to their findings, fatigue can impair the coordination and function of the core muscles, which are necessary for creating a stable base and performing motions that are proportional to the body's organs.

The findings of the current study showed that there was a significant increase in SLBT-D, SLBT-ND post fatigue of fatigue group compared with that of control group, which concluded that fatigue negatively affects the balance. Likewise,there was a significant increase in 20-m running sprint time post fatigue in the between groups comparison and there was a significant decrease in THT post fatigue in the fatigue group which is suggested that the player performance decreased after fatigue.

Tong et al. (2014) finding was in line with the findings in this study, where they stated that fatigue in trunk muscles negatively affects the balance and running performance. Additionally, **Ghamkhar.(2019)** noted that neuromuscular control is particularly susceptible to the cumulative negative impacts of fatigue during competitions, which can lead to improper movement patterns and an increased likelihood of injury. Since football players are more prone to injuries when their dynamic and static postural stability is inadequate, **Fard et al.(2022)**came to the conclusion that this is an essential skill for football players to have.

Findings from this study are in line with previous research that has linked fatigue to a change in gait style during running, which in turn reduces sprint as well as jump performance **(Mendez-Villanueva et al., 2008; Patterson et al., 2011; Gathercole et al., 2015).** Further, it has been shown that during a fatigue-inducing repeated sprint protocol, large decrements in accelerometer load and decline in the vertical acceleration of the center of mass during runningwas previously detected by **(Akenhead et al. 2017, Barrettet al. 2014and Cormack et al. 2013).**

The findings of this study were agreed with **Silva et al. (2018)**who reported the use of different jump tests as measures of neuromuscular function following exercise, with reductions in jump performance reported for up to 72 h. In the same context**Brownstein et al. (2017)**observeddecreases in jump height immediately post-match play.According to **Claudino et al. (2017),** the jump tests assess the level of mechanical and neuromuscular fatigue in athletes, as well as their strength, endurance, speed, as well as plyometric training benefits. Thus, jump performance has been identified by several researches as an objective indicator of fatigue and athletic performance**(Claudino, 2017, Doeven 2018 and Hader 2019).**

Inthis study, RSA test was applied as a fatigue protocol to induce fatigue in the fatigue group.As noted by **Doeven et al. (2018),** ball-implement sports like football and rugby have a longer recovery period for sprint performance than other ball sports. Consequently, it appears crucial to have a way to measure factors that reveal players' levels of fatigue.Also, **Chaouachi et at., Glaister 2008 and Armada 2022** stated that theimpact of fatigue on performance is confirmed through the RSA protocol. The RSA protocol is considered a frequent technique for evaluating sprint performance,however there are different formulas to calculate fatigue in RSA testsCharron 2020. Several sports incorporate repeated sprints, such as basketball, football, as well as rugby. The RSA of male football players was assessed using several different protocols. The following finding was established after reviewing the data given in these studies: With each additional repetition, the sprint became slower**(Little, T., & Williams, A. G. 2007).** The buildup of fatigue is probably responsible for this. Evidence of increasing fatigue from the first to the second half of a football game gives support to this concept **(Angius et al2013, Selmi et al. 2016 and Dent et al. 2015).**A young football player's fatigue can be measured using the fatigue index, which is utilized in the RSA test.

Key points: The fatigue can cause decrease in trunk endurance, balance and running and jump performance in the mal adolescent football playerswith more deterioration in balance and performance which can cause increase the risk of injury.

Implications: These findings indicate that adolescent football players should focus on exercises that increase their endurance, decrease the training load and increase the recovery time to decrease fatigue level and should include core stability exercises, balance training, running exercises and jumping training in the injury prevention exercises and training routine for the adolescent football players.

Recommendations: The current study was limited to only male players; we recommend further studies withfemale players to reinforce the current findings.

Ethical considerations:

The authors have stated that they are not associated with or financially supported by any company, group, or individual that would have an interest in the article's content or subjects. Ethical review by the faculty of physical therapy at Cairo University gave their approval to the study's protocol (**NCT06069635**), and it was also included in the clinical trial registry**.**

REFERENCES

- Akenhead R, Marques JB, Paul DJ. Accelerometer load: a new way to measure fatigue during repeated sprint training?. Science and Medicine in Football. 2017 May 4;1(2):151-6.
- Angius L, Olla S, Piras F, Mura R, Ibba G, Todde F, Cominu M, Pinna M, Tocco F, Concu A, Crisafulli A. Indexes of physical capacity and repeated sprint ability of young soccer players. Sport Sciences for Health. 2013 Apr;9:1-6.
- Armada-Cortés E, Benítez-Muñoz JA, Sánchez-Sánchez J, San Juan AF. Evaluation of neuromuscular fatigue according to injury history in a repeat sprint ability test, countermovement jump, and hamstring test in elite female soccer players. Applied Sciences. 2022 Mar 14;12(6):2970.
- Aytar A, Pekyavas NO, Ergun N, Karatas M. Is there a relationship between core stability, balance and strength in amputee soccer players? A pilot study. Prosthetics and orthotics international. 2012 Sep;36(3):332-8.

- Aziz AR, Tan Hun Yau F, Chuan TK. The 20m Multistage Shuttle Run test: Reliability, Sensitivity and its Performance Correlates in trained soccer players. Asian Journal of Exercise & Sports Science. 2005 Nov 1;2(1).
- Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. Journal of sports sciences. 2006 Jul 1;24(07):665-74.
- Barrett S, Midgley A, Lovell R. PlayerLoad™: reliability, convergent validity, and influence of unit position during treadmill running. International journal of sports physiology and performance. 2014 Nov 1;9(6):945-52.
- Brownstein CG, Dent JP, Parker P, Hicks KM, Howatson G, Goodall S, Thomas K. Etiology and recovery of neuromuscular fatigue following competitive soccer match-play. Frontiers in physiology. 2017 Oct 25;8:831.
- Brumitt J, Matheson JW, Meira EP. Core stabilization exercise prescription, part I: current concepts in assessment and intervention. Sports Health. 2013 Nov;5(6):504-9.
- Buchheit, M., Mendez-Villanueva, A., Delhomel, G., Brughelli, M., &Ahmaidi, S. (2010). Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training. *The Journal of Strength & Conditioning Research*, *24*(10), 2715-2722.
- Calderón-Pellegrino G, Gallardo L, Paredes-Hernández V, García-Unanue J, Giménez JV, Colino E, Felipe JL, Sanchez-Sanchez J. Influence of artificial turf temperature on physical performance and muscle contractile properties in football players after a repeated-sprint ability test. Scientific Reports. 2020 Jul 29;10(1):12747.
- Chaouachi A, Manzi V, Wong DP, Chaalali A, Laurencelle L, Chamari K, Castagna C. Intermittent endurance and repeated sprint ability in soccer players. The Journal of Strength & Conditioning Research. 2010 Oct 1;24(10):2663-9.
- Charron J, Garcia JE, Roy P, Ferland PM, Comtois AS. Physiological Responses to Repeated Running Sprint Ability Tests: A Systematic Review. International journal of exercise science. 2020;13(4):1190.
- Claudino JG, Cronin J, Mezêncio B, McMaster DT, McGuigan M, Tricoli V, Amadio AC, Serrão JC. The countermovement jump to monitor neuromuscular status: A meta-analysis. Journal of science and medicine in sport. 2017 Apr 1;20(4):397-402.
- Cormack SJ, Mooney MG, Morgan W, McGuigan MR. Influence of neuromuscular fatigue on accelerometer load in elite Australian football players. International journal of sports physiology and performance. 2013 Jul 1;8(4):373-8.
- Cressey EM, West CA, Tiberio DP, Kraemer WJ, Maresh CM. The effects of ten weeks of lower-body unstable surface training on markers of athletic performance. The Journal of Strength & Conditioning Research. 2007 May 1;21(2):561-7.
- Dent JR, Edge JA, Hawke E, McMahon C, Mündel T. Sex differences in acute translational repressor 4E-BP1 activity and sprint performance in response to repeated-sprint exercise in team sport athletes. Journal of Science and Medicine in Sport. 2015 Nov 1;18(6):730-6.
- Doeven SH, Brink MS, Kosse SJ, Lemmink KA. Postmatch recovery of physical performance and biochemical markers in team ball sports: a systematic review. BMJ open sport & exercise medicine. 2018 Feb 1;4(1):e000264.
- Dragoo JL, Braun HJ. The effect of playing surface on injury rate: a review of the current literature. Sports Medicine. 2010 Nov;40:981-90.

- Dupont G, Nedelec M, McCall A, McCormack D, Berthoin S, Wisløff U. Effect of 2 soccer matches in a week on physical performance and injury rate. The American journal of sports medicine. 2010 Sep;38(9):1752-8.
- Enoka RM, Duchateau J. Muscle fatigue: what, why and how it influences muscle function. The Journal of physiology. 2008 Jan 1;586(1):11-23.
- Fard RB, Atri AE, Yazdi NK, Shahtahmassebi B. Assessing changes in static and dynamic postural stability in youth football players following the FIFA 11+ injury prevention program. Science & Sports. 2022 May 1;37(3):215-e1.
- Farzami A, Anbarian M. The effects of fatigue on plantar pressure and balance in adolescent volleyball players with and without history of unilateral ankle injury. Science & Sports. 2020 Feb 1;35(1):29-36.
- Fessi MS, Zarrouk N, Di Salvo V, Filetti C, Barker AR, Moalla W. Effects of tapering on physical match activities in professional soccer players. Journal of sports sciences. 2016 Dec 16;34(24):2189-94.
- Fitzpatrick JF, Akenhead R, Russell M, Hicks KM, Hayes PR. Sensitivity and reproducibility of a fatigue response in elite youth football players. Science and Medicine in Football. 2019 Jul 3;3(3):214-20.
- Gathercole RJ, Sporer BC, Stellingwerff T, Sleivert GG. Comparison of the capacity of different jump and sprint field tests to detect neuromuscular fatigue. The Journal of Strength & Conditioning Research. 2015 Sep 1;29(9):2522-31.
- Ghamkhar L, Kahlaee AH. The effect of trunk muscle fatigue on postural control of upright stance: A systematic review. Gait & posture. 2019 Jul 1;72:167-74.
- Glaister M, Howatson G, Pattison JR, McInnes G. The reliability and validity of fatigue measures during multiple-sprint work: an issue revisited. The Journal of Strength & Conditioning Research. 2008 Sep 1;22(5):1597-601.
- Güler Ö, Aras D, Akça F, Bianco A, Lavanco G, Paoli A, Şahin FN. Effects of aerobic and anaerobic fatigue exercises on postural control and recovery time in female soccer players. International Journal of Environmental Research and Public Health. 2020 Sep;17(17):6273.
- Hader K, Rumpf MC, Hertzog M, Kilduff LP, Girard O, Silva JR. Monitoring the athlete match response: Can external load variables predict post-match acute and residual fatigue in soccer? A systematic review with meta-analysis. Sports medicine-open. 2019 Dec;5(1):1-9.
- Hajmirzaei Tafreshi M, Minoonejad H, Seidi F. Effect of Fatigue on the Core Muscle Endurance in Female Athletes With and Without Non-specific Chronic Low Back Pain .2023 Apr 10;13(2):135-46.
- Herbst E, Hoser C, Hildebrandt C, Raschner C, Hepperger C, Pointner H, Fink C. Functional assessments for decision-making regarding return to sports following ACL reconstruction. Part II: clinical application of a new test battery. Knee Surgery, Sports Traumatology, Arthroscopy. 2015 May;23:1283-91.
- Hopker JG, Coleman DA, Wiles JD, Galbraith A. Familiarisation and reliability of sprint test indices during laboratory and field assessment. Journal of sports science & medicine. 2009 Dec;8(4):528.
- Ishizuka T, Hess RA, Reuter B, Federico MS, Yamada Y. Recovery of time on limits of stability from functional fatigue in Division II collegiate athletes. The Journal of Strength & Conditioning Research. 2011 Jul 1;25(7):1905-10.

- Jadczak Ł, Grygorowicz M, Wieczorek A, Śliwowski R. Analysis of static balance performance and dynamic postural priority according to playing position in elite soccer players. Gait & posture. 2019 Oct 1;74:148-53.
- Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. Sports medicine. 2006 Mar;36:189-98.
- Knicker AJ, Renshaw I, Oldham AR, Cairns SP. Interactive processes link the multiple symptoms of fatigue in sport competition. Sports medicine. 2011 Apr;41:307-28.
- Krishna HS, Shetty S, Raj AS. Relationship between core endurance and dynamic balance in college level football players: A pilot study. Int J Phys Educ Sports Health. 2020;7(5):149-53.
- Little T, Williams AG. Effects of sprint duration and exercise: rest ratio on repeated sprint performance and physiological responses in professional soccer players. The Journal of Strength & Conditioning Research. 2007 May 1;21(2):646-8.
- Lloyd RS, Oliver JL, Kember LS, Myer GD, Read PJ. Individual hop analysis and reactive strength ratios provide better discrimination of ACL reconstructed limb deficits than triple hop for distance scores in athletes returning to sport. The Knee. 2020 Oct 1;27(5):1357-64.
- Mendez-Villanueva A, Hamer P, Bishop D. Fatigue in repeated-sprint exercise is related to muscle power factors and reduced neuromuscular activity. European journal of applied physiology. 2008 Jul;103:411-9.
- Meyer T, Kellmann M, Ferrauti A, Pfeiffer M, Faude O. The measurement of recovery and regeneration requirements in football. Deutsche Zeitschrift fur Sportmedizin. 2013 Jan 1;64(1):28-34.
- Müniroğlu S, Deliceoğlu G. Competition Analysis and Observation Techniques in Football. Ankara: Ankara University Printing House. 2008.
- Naumann T, Kindermann S, Joch M, Munzert J, Reiser M. No transfer between conditions in balance training regimes relying on tasks with different postural demands: specificity effects of two different serious games. Gait & posture. 2015 Mar 1;41(3):774-9.
- Paillard T, Noe F, Riviere T, Marion V, Montoya R, Dupui P. Postural performance and strategy in the unipedal stance of soccer players at different levels of competition. Journal of athletic training. 2006;41(2):172.
- Paradisis GP, Zacharogiannis E, Mandila D, Smirtiotou A, Argeitaki P, Cooke CB. Multi-stage 20-m shuttle run fitness test, maximal oxygen uptake and velocity at maximal oxygen uptake. Journal of human kinetics. 2014 Jun 6;41:81.
- Patterson M, McGrath D, Caulfield B. Using a tri-axial accelerometer to detect technique breakdown due to fatigue in distance runners: a preliminary perspective. In2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society 2011 Aug 30 (pp. 6511-6514). IEEE.
- Pau M, Ibba G, Attene G. Fatigue-induced balance impairment in young soccer players. Journal of athletic training. 2014 Aug 1;49(4):454-61.
- Pojskic H, McGawley K, Gustafsson A, Behm DG. The reliability and validity of a novel sport-specific balance test to differentiate performance levels in elite curling players. Journal of Sports Science & Medicine. 2020 Jun;19(2):337.
- Pollock KM. Star Excursion Balance Test as a predictor of lower extremity injury in high school football players. Journal of orthopaedic& sports physical therapy. 2010 Dec;36(12):911-9.

- Rambaud AJ, Rossi J, Neri T, Samozino P, Edouard P. Evolution of Functional Recovery using Hop Test Assessment after ACL Reconstruction. International journal of sports medicine. 2020 Sep;41(10):696-704.
- Raschner C, Lembert S, Mildner E, Platzer HP, Patterson C. EntwicklungeinessensomotorischenFeedbacktrainingsgerätes für den begleitendenEinsatz in der neuronalen Rehabilitation. B&G Bewegungstherapie und Gesundheitssport. 2008 Dec;24(06):241-5.
- Saporito G, Jernstedt G, Miller H. Test-retest reliability and validity of the plank exercise.2015.
- Selmi MA, Sassi RH, Yahmed MH, Moalla W, Elloumi M. Effect of between-set recovery durations on repeated sprint ability in young soccer players. Biology of sport. 2016 Jun;33(2):165-72.
- Silva JR, Rumpf MC, Hertzog M, Castagna C, Farooq A, Girard O, Hader K. Acute and residual soccer match-related fatigue: a systematic review and meta-analysis. Sports Medicine. 2018 Mar;48:539-83.
- Soligard T, Schwellnus M, Alonso JM, Bahr R, Clarsen B, Dijkstra HP, Gabbett T, Gleeson M, Hägglund M, Hutchinson MR, Van Rensburg CJ. How much is too much?(Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. British journal of sports medicine. 2016 Sep 1;50(17):1030-41.
- Tong TK, Wu S, Nie J, Baker JS, Lin H. The occurrence of core muscle fatigue during high-intensity running exercise and its limitation to performance: the role of respiratory work. Journal of sports science & medicine. 2014 May;13(2):244.
- Tong TK, Wu S, Nie J. Sport-specific endurance plank test for evaluation of global core muscle function. Physical Therapy in Sport. 2014 Feb 1;15(1):58-63.
- und Schülern S. Sensorimotoric Feedback Performance in obese and normal-Weight 11 to 15 year-old School children. deutScheZeitSchriFt Für SPortmediZin. 2012;63(2).
- Yaggie JA & McGregor SJ. Effects of isokinetic ankle fatigue on the maintenance of balance and postural limits. Archives of physical Medicine and Rehabilitation. 2002 Feb 1;83(2):224-8.
- Zago M, David S, Bertozzi F, Brunetti C, Gatti A, Salaorni F, Tarabini M, Galvani C, Sforza C, Galli M. Fatigue induced by repeated changes of direction in élite female football (soccer) players: impact on lower limb biomechanics and implications for ACL injury prevention. Frontiers in bioengineering and biotechnology. 2021 Jul 5;9:666841.