ORIGINAL ARTICLE

Reliability and Validity of a Short Duration High-intensity Soccer-specific Fatigue Simulation for Youth Players

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ABSTRACT

Introduction: This study investigated the reliability and validity of a newly developed high-intensity Youth Soccer Fatigue Simulation (YoSFS^5). **Methods:** Twenty recreational youth soccer players (age:15.9±0.87 years old, BMI =19.52±2.58 kg/m2) performed the YoSFS^5 in 5 minutes after performing a dynamic warming-up. Heart rate (HR), rate of perceived exertion (RPE), and countermovement jump (CMJ) height were recorded immediately after completing the simulation. After a week, the participants repeated the same procedure and measurements. Data analysis was performed for the intra-class coefficient of correlation (ICC), standard error of measurement (SEM), and expressed as a coefficient of variation (CV%) . **Results:** Relative reliability showed ICC for RPE (0.92) (95% CI 0.79-0.97)) and CMJ (0.85) (95% CI 0.79-0.97) were excellent. Meanwhile, the ICC for HR (.72) (95% CI 0.31-0.89) was considered good. The absolute reliability showed a small percentage of CVs for HR, RPE, and CMJ at 0.9%, 5.5%, and 8.35%, respectively. The validity of the study shows the mean HR (174.0 beats/min^{-1}) and RPE (18). **Conclusion:** The YoSFS^5 measurements show that the simulation is valid and reliable. Therefore, the newly developed fatigue simulation may induce fatigue among youth soccer players as it is highly reproducible.
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INTRODUCTION

Owing to the popularity of soccer, the current trend is to start playing at a very young age (1). Numerous soccer academies have been opened to attract and train young soccer players hoping to become professional. However, training in and playing soccer at a young age may lead to a high risk of injury (2). Approximately 15 to 20 injuries per 1,000 playing hours are reported among young soccer players (3). Moreover, the percentage of young soccer players treated in hospital emergency departments increased 78% yearly from 1990 to 2014, double the rate of adult injuries (4). A few factors are suggested for why young players have a high risk of injury, including aggressive behavior against the rules, rapid skeletal growth, muscle hyper-flexibility, muscle imbalance, lack of motor skills, and fatigue (2,5,6).

Soccer is a sport that requires the massive activation of aerobic and anaerobic energy systems to fulfill muscle energy demands. The need to fulfill the body's demands during a soccer match, especially at the end of a game, may lead to work rate reduction (7) and diminished muscular force output (8), which in turn may lead to a decline in playing performance (9). Furthermore, soccer players may experience fatigue toward the end of a game, affecting their playing performance (10). In a sports setting that requires continuous muscle exertion, Meeusen et al. described fatigue as a metabolic endpoint when muscle glycogen is depleted, plasma glucose concentrations are reduced, and plasma free fatty acid levels are reduced are elevated (11). Moreover, previous studies established fatigue as one of the major risk factors of injury in sports (12–14). Other studies determined that fatigue increases the risk of injury to the anterior cruciate ligament (ACL) (15) and hamstring (14). ACL injuries have severe implications for players. A few studies showed that an ACL injury might necessitate long rehabilitation periods for players, affect players' financials and those of their team, end careers prematurely, and place players at risk for posttraumatic osteoarthritis (3,16–18). Moreover, such studies claimed that recurrent injury after ACL reconstruction increases 30 to 40 times, and approximately 1 in 4 young players is likely to experience an ACL injury again during his/her career (19). An ACL injury that occurs during the fatigue stage may be associated with physiological changes in muscles (20), an imbalance between the quadriceps concentric and hamstring eccentric ratio (21), weakness in muscles (15), and alterations in postural mechanics during the late stage of a game (22).

Due to the negative consequences of fatigue, establishing a reliable and valid assessment tool for young players for soccer games is necessary. A specific fatigue assessment tool is needed to identify players' capacity and risk of injury (23,24). Furthermore, ensuring that return-to-play assessments involve examining the fatigue state is crucial. According to Melick et al., players who underwent ACL reconstruction have significantly reduced movement quality compared with healthy subjects under fatigue, which increases their risk of reinjuring their ACL (25). Given that young soccer players have a high risk of injury due to the factors as mentioned earlier, an assessment tool specific to their growth stage and skills and the nature of soccer games may be necessary.

Several fatigue simulations have been developed; however, most have limitations, such as being time-consuming (23,26–29), not specific to the nature of soccer games (23,24,26–28), and being suitable only for adult players (15,27). Generally, most fatigue simulations do not address the specific nature of soccer games. For instance, some simulations are performed on the floor with a 20 meter distance (30–32), whereas others are conducted on a treadmill (33,34). In the previous study by Aldous et al., lab-or field-based soccer-specific fatigue simulations should be designed to generate a fatigue representation equal to that in a real soccer match play (35).

The development and evaluation of short-term protocols should include match play-induced fatigue assessments to reduce the risk of injury. Bishop et al. suggested that a simulation be modified based on a sport's nature or specificity (36). We suggest that soccer fatigue simulations incorporate activities such as shooting, passing, and heading to mimic actual soccer activities. Thus, we have developed Youth Soccer Fatigue Simulation(YoSFS5), which is feasible for young soccer players, and several soccer-specific movements, such as kicking, jumping, heading, and sprinting with a ball, were included in the simulation protocol. Therefore, the purpose of this study is to identify the reliability and validity of a newly developed high-intensity, short-duration youth soccer fatigue simulation (YoSFS^5).

MATERIALS AND METHODS

Participant

This study is a cross-sectional research with a test-retest design. Good reliability indicates that the simulation will yield identical findings under varied conditions, assuming nothing else has changed. Meanwhile, good validity is a subtler concept of the closeness of what is being measured. Sample size calculation was conducted using the Sample size calculator (web) by Arifin with selected the Intraclass Correlation Coefficient (ICC) – Estimation. To achieve expected reliability (ICC) (ρ):0.6, Precision (± expected): 0.6, a minimum number of 6 participants is required for this study(37). A 20% was added to reduce the possibility of attrition rate. Therefore, 8 participants should recruit in objective 2. However, we manage to get 20 participants of young male recreational soccer players from a secondary school soccer team. The participants of this study were young men between the ages of 15 and 17 years who regularly played soccer three to five times a week for 40 to 60 minutes per session. Moreover, the participants were nonsmokers. Participants with a history of the lower extremity or low back pains or cardiovascular or systemic conditions that limit physical activity or who experienced a lower limb injury within the last six months, use ergogenic aids or medication, or answered "yes" on the Physical Activity Readiness Questionnaire (PAR-Q) were excluded from the study. The study procedure was approved by the Institution Research Ethics Committee (600-IRMI [5/1/16]). Informed consent was obtained from the participants' parents/guardians before the test was conducted. The study was conducted at a high-performance laboratory at the university's Physiotherapy Department. This laboratory was selected owing to its ample space, optimal room temperature (28 °C–31.1 °C), and lack of external interference.

Developmental Procedure of YoSFS^5

The YoSFS^5 was modified from a previous study (15). The modifications included changes to the simulation distance, soccer activity repetitions, and soccer activity order. In addition, heart rate (HR), rate of perceived exertion (RPE), and counter movement jump (CMJ) height were monitored in the protocol to represent intensity and fatigue level.

A preliminary study was conducted to determine whether the YoSFS^5 achieved a level of fatigue indicated by the following criteria: (1) HR of 161–175 beats/min^{-1} and (2) RPE of > 17. These criteria were similar to the overall pattern observed in the youth 90-min soccer-specific aerobic field test (Y-SAFT^{90}) and during actual gameplays for youths (26). In addition, these criteria for indicating fatigue were considered practical and suitable by a panel of experts in soccer training and coaching. Figure 1 presents the YoSFS^5 course. The YoSFS^5 distance was modified to 12 meters to make the protocol feasible for young soccer players. Moreover, several soccer-specific movements, such as jogging, kicking, ball passing, jumping, heading, and sprinting with a ball, were included in the simulation protocol (refer Table I). All these activities are normal as mentioned in some previous studies(38) and all these have been discussed with the experts including soccer coaches. At the start of the simulation, the participants were asked to stand at point A and wait for the audio recording cues. Next, the participants were requested to step forward from point A to B and kick the ball back to point A. This movement activity was repeated five times. Then, the participants were asked to run and stand at point D.

Subsequently, the participants were told to jog from point D to E then back to point D, following the cues from the audio recording. Next, the participants were instructed to jog to point F, zig-zag between the poles to point G, jog back to point F, then jog back to point G. The participants were then requested to go to point A to head a ball, step forward from point A to B and double leg jump to head the ball (a ball was thrown above the rope at 80% of the participants' CMJ height), then return to point A. This movement was repeated five times. Next, from point D, the participants were instructed to run sideways to point E then back to point D. The participants were told to continue jogging to point F, zig-zag between the poles to point G, then jog back to the first pole and back to point G. After this activity, the participants performed the agility drill by running to point H, hopping on one foot per square, then running backwards to shoot the ball with maximal effort and accuracy at point I and the goal post. Next, the participants performed the CMJ at point C then jogged to point D. Subsequently, the participants were instructed to jog from point D to E then back to point D. They were told to continue jogging to point F, zig-zag between the poles to point G, then jog back to point F and back to point G. From point G, the participants made a final sprint with a ball through point J to point D. The cycle was repeated after one round/cycle. The entire YoSFS[5] took five minutes to complete.

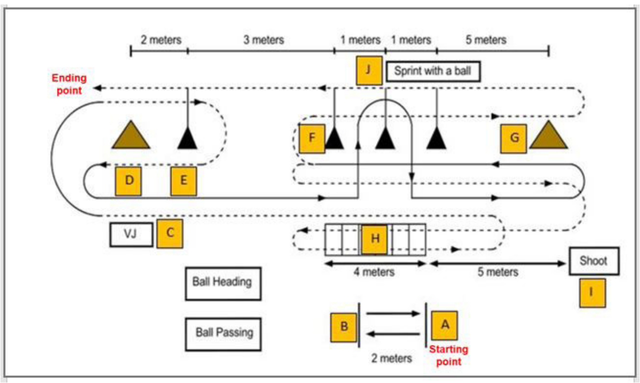

Fig. 1. A diagrammatic representation of the fatigue simulation activity profile.

Table I. Activity profiles of YoSFS[5] compared with the activity profiles of SAFT[5]

No	Activity YSFS[5]	Activity SAFT[5]	Speed (m/s)	Time (s)
0	5x Ball Passing	10 x scissors		
1	Stand	Stand	0	4
2	Jog	Jog	2.86	10
3	5x Ball double-leg jump heading	CMJ	1.39	17
4	Stride	Stride	4.17	7
5	Agility ladder drill + 1 x Ball shooting	Agility ladder drill	1.39	17
6	CMJ + jog	Jog	2.86	10
7	Sprint with a ball	Sprint	5.58	6
8	Stand	Stand	0	4
9	Jog	Jog	2.86	10
10	5x Ball Passing	10 x scissors	1.39	17
11	CMJ + jog	Jog	2.86	10
12	5x Ball double-leg jump heading	CMJ	1.39	17
13	Stride	Stride	4.17	7
14	Agility ladder drill + 1 x Ball shooting	Agility ladder drill	1.39	17
15	Stand	Stand	0	4
16	Jog	Jog	2.86	10
17	5x Ball Passing	10 x scissors	1.39	17
18	CMJ + jog	Jog	2.86	10
19	Jog	Jog	2.86	10
20	Jog	Jog	2.86	10
21	5x Ball double-leg jump heading	CMJ	1.39	17
22	CMJ + jog	Jog	2.86	10
23	Agility ladder drill + 1 x Ball shooting	Agility ladder drill	1.39	17
24	Stride	Stride	4.17	7
25	Stand	Stand	0	4
26	5x Ball Passing	10 x scissors	1.39	17
27	Jog	Jog	2.86	10
28	Sprint with a ball	Sprint	1.39	6
29	CMJ			

CMJ: countermovement jump

Instrumentations

Heart rate (HR)

The HR measurement counted the number of heartbeats per minute. In this study, the Polar heart rate system (Electro, Finland) was used, which demonstrated satisfactory relative and absolute reliability, with an intraclass correlation coefficient (IIC) of 0.88 and a coefficient of variation (CV) of 1.8%, respectively (35). The participants wore a chest strap with a transmitter unit. The strap was fitted to the participants' chest circumference. The transmitter unit was placed firmly against the skin just below the participants' chest muscles. The participants were required to inform the researcher of the HR value that appeared on a watch immediately after completing the YoSFS[5].

Rating of Perceived Exertion (RPE)

The RPE refers to the degree of perception of local sensations, including those from the circulatory, respiratory, metabolic, skeletal muscle, and peripheral systems. It is a useful and practical tool for monitoring internal load during soccer training (39). A Borg scale ranging from 6 (no exertion) to 20 (maximum exertion) was used in this study. The RPE demonstrated satisfactory reliability, with an ICC of > 0.75 and a CV of < 10% (15). The participants were required to inform the researcher of their RPE scale immediately after completing the YoSFS[5] for documentation. Moreover, the participants were instructed to disregard sensations such as leg pain or shortness of breath and to focus on the overall feeling of exertion. The RPE 6-to-20 scale was printed and placed on the wall near the simulation area (near point D) to guide the participants in rating their perceived exertion based on the scale. Generally, the fatigue state is achieved when the RPE reaches ≥ 17 (very hard) (40).

Counter movement jump (CMJ)

The CMJ assesses jump height. The CMJ (free arm) height was measured with the My Jump 2 application (version 6.0.3) (41). The participants were allowed to swing their arms when performing the CMJ. My Jump 2 is an application that records a video using the high-speed camera of a mobile smartphone and calculates jump outcomes from the fly time. My jump 2 is valid and reliable for measuring CMJ, with satisfactory relative reliability (ICC ≥ 0.88) and absolute reliability (CV < 10%) (41). The weight, leg length (distance from the greater trochanter of the femur to the tip of the toe, with the participants lying on their back while keeping a full ankle plantar flexion), and 90 degree-height (vertical distance from the greater trochanter of the femur to the ground in an optimal knee-flexed position at a 90° knee angle) of the participants were inputted into the My Jump 2 application. After the participants completed the simulation, they were instructed to stand upright with their feet shoulder-width apart. Then, CMJ with a free arm was measured by instructing the participants to perform a rapid downward movement by flexing their knees and hips then immediately extending their knees and hips to jump as high as possible. An iPhone 6 was used to record two CMJ trials. In the My Jump 2 application, through a video, "take off" was selected in the first frame, where no foot touches the ground, and "landing" was selected in the first frame, where at least one foot has contact with the ground. A second CMJ trial was conducted with the same procedure. The CMJ height was based on the best score of the two jumps and recorded to the nearest 0.1 centimeter.

Procedures

The demographic data of the participants, including age, height (cm), body weight (kg), and body mass index (BMI; kg/m^2), were recorded prior to the fatigue simulation. All the participants were screened using the PAR-Q questionnaire to detect symptoms and risk factors of cardiovascular diseases and general health and wellbeing. In the absence of health conditions, the participants were scheduled for the data collection. They were instructed to avoid strenuous exercise 48 hours prior to and eating a meal two hours before taking the test. During the procedure, first, the participants were engaged in a familiarization session for the YoSFS[5], HR, RPE, and CMJ measurement protocols. The YoSFS[5] activity sequence was presented using audio-recorded verbal cues. During the simulation, the HR, RPE, and CMJ height of the participants were measured. If a participant was unable to follow the audio recording, then verbal encouragement was provided to increase motivation.

The testing trial was conducted at least three days after the familiarization session. Complete attire, including a shirt, shorts, and shoes (KRONOS, series: KFW-5924, made in the USA), were provided to the participants to wear during the testing. The participants used the same sports shoes to prevent any bias as a study stated that different types of shoes resulting significant differences in loading distribution(42). During the trial sessions, the participants were instructed to perform dynamic warm-up exercises using the FIFA 11+ protocol, followed by a five-minute passive rest. Next, CMJ height was measured before the simulation to determine the height of the ball heading (80% of the CMJ). Once the setup was ready, the participants performed the YoSFS[5]. After completing the fatigue simulation, the participants' HR, RPE, and CMJ were immediately recorded. This study included test-retest reliability; therefore, the same procedure was conducted a week later to allow for a washout period. Meanwhile, the validity of this study was determined based on Hůlka et al. according to the test's inherent characteristics by measuring HR and RPE (43).

Data Analysis

Data analysis was performed with Statistical Package for Social Sciences (SPSS) (version 25; SPSS inc, Chicago, IL), with a significance level set at $p < 0.05$. Descriptive analysis was used for the demographic and baseline (age, height, weight, BMI, HR, RPE, and CMJ height) data. The test of normality using the Shapiro–Wilk test was nonsignificant ($p > 0.05$), indicating an assumption of normality in the data distribution. An independent t-test was used to determine the differences between the test and retest. Meanwhile, relative reliability was calculated using the ICC, with a 95% confidence interval from a two-way mixed model. Absolute reliability is a standard error of measurement (SEM) for every variable, with the following formula: SD dif/ $\sqrt{2}$, where SD represents standard deviation, and dif represents the mean difference between the test and retest. CV was calculated using the following formula: (SEM/mean of tests) x 100 (44). The ICC was interpreted according to the following criteria: between 0.75 and 1.00 is excellent, between 0.41 and 0.74 is satisfactory, and between 0.00 and 0.40 is poor (45). The Bland–Altman plot with a 95% limit of agreement was also determined. The mean HR and RPE from the two trials were used for the validity analysis.

RESULT

A total of 20 young soccer players participated in this study (age = 15.97 years ± 0.87 years, height = 166.97 ± 6.0 cm, weight = 54.60 ± 8.89kg, BMI = 19.52 ± 2.58 kg/m^2).

Reliability

The reliability of the test is presented as the mean and SD of the test-retest, p-value, ICC, SEM, and CV in Table II. The comparison between the test and retest showed no significant differences in HR, RPE, and CMJ (p = 0.288, p = 0.214, and p = 0.551). The ICC of the RPE was 0.92 (95% CI 0.79–0.97) and that of the CMJ was 0.85 (95% CI 0.79–0.97), thereby demonstrating excellent reliability. Meanwhile, the HR ICC of 0.72 (95% CI 0.31–0.89) was satisfactory. Moreover, the SEM of the HR, RPE, and CMJ exhibited high reliability (1.09, 0.99, and 2.21). The small CV of the HR, RPE, and CMJ was 0.9%, 5.5%, and 8.35%, respectively. A CV of less than 10% is regarded as an acceptable level of reliability (46). The Bland–Altman plot of the HR, RPE, and CMJ, with a 95% limit of agreement, was close to the mean line and ranged between the upper and lower limits of agreement, as presented in Figure 2. All variables indicated a high level of agreement, and differences were similar for all ranges.

Validity

The analysis showed that the HR mean for the first and second trials was 174.2 ± 1.8 beats/min $^{-1}$ (85 ± 0.9% HR max) and 173.8 ±1.7 beats/min^{-1} (84.8 ± 0.8% HR max), respectively, after the YoSFS[5]. During the simulation, the RPE mean for the first and second trials was 17.9 (SD ± 1.17) and 18.1 (SD ±1.37), respectively. The results of the RPE demonstrated that the participants were between the hard and extremely hard stages, thereby experiencing psychophysiological fatigue.

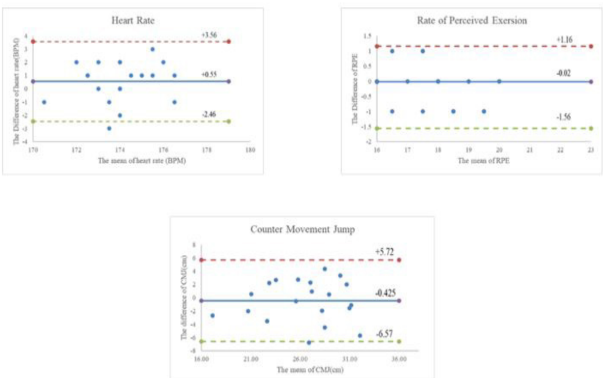

Fig. 2 Bland-Altman plot with 95% limits of agreement for HR, RPE and CMJ

Table II. Mean Peak and SD of test-retest, p-value, intraclass coefficient of correlation, standard error of measurement and coefficient of variation

	Trial 1 (mean± SD)	Trial 2 (mean± SD)	p-value	ICC(95% CI)	SEM	CV (%)
Heart Rate(beat/min)	174.2 ± 1.8	173.8 ±1.7	0.288	0.72(0.31-0.89)	1.09	0.89
Rate of Perceived Exertion	17.9 ± 1.17	18.1 ±1.37	0.214	0.92(0.79-0.97)	0.99	5.5
Counter Movement Jump (cm)	26.25 ±4.35	26.68 ±4.31	0.551	0.85(0.63-0.94)	2.21	8.35

*significant at <0.05,
CI: confidence interval, ICC: intraclass coefficient of correlation, SEM: standard error of measurement, CV: coefficient of variation.

DISCUSSION

The objective of this study was to determine the test-retest reliability and validity of a newly developed high-intensity short-duration YoSFS[5]. This high-intensity, short-duration YoSFS[5] was developed to induce fatigue among young soccer players according to the nature of activities of a soccer match. The reliability of a new performance test should be determined before it is used in practice. The study presented the following key findings. 1) The young soccer players' HR, RPE, and CMJ height demonstrated satisfactory to excellent reliability (ICC > 0.70) in the test-retest. 2) The YoSFS[5] was a valid tool for inducing fatigue among the young soccer players, as changes in the HR and RPE were consistent with those in the Y-SAFT[90] and in actual matches. Therefore, the simulation was valid and demonstrated high reproducibility. Thus, it can be used to examine changes in fatigue level as a predictor of risk of injury in young soccer players.

YoSFS[5] Measurement Validity

This study monitored HR and RPE during the simulation to determine and verify internal reactions with the simulation and match reactions (15,26,43). The findings showed that the HR grand mean was 174.0 beats/min^{-1} (84.9% HR max) after the YoSFS5, slightly lower than SAFT[5] (89±4% HR max) (15). YoSFS[5] HR max exhibited a pattern similar to that of the HR max of an actual soccer match for young professional and recreational players (81%–88% HR max and 82.2% HR max, respectively) (26,47). According to Bossuyt et al., the validity of SAFT[5] depended on the HR and RPE, which needed a similar overall pattern during SAFT[90] (15). As mentioned in the method session that, YoSFS[5] should represent the same overall pattern as during the Y-SAFT[90]. This is because both simulation participated by the youth population. In this study, the mean HR max of the YoSFS[5] was just slightly higher than that of the Y-SAFT[90]. This result maybe because of the different backgrounds of the participants. The Y-SAFT[90] was conducted among elite–youth players, whereas the YoSFS[5] was utilized for recreational soccer players. Elite soccer players have a high percentage of type-1 fibers (slow/fatigue-resistant fibers) and high aerobic fitness and thus may have increased ability to fight fatigue (48). Compared with an actual match soccer profile, the mean HR max of the YoSFS[5] was between 81%–88%. Therefore, the YoSFS[5] could acceptably replicate the internal load of an actual match.

The RPE can represent athletes' perception of physical and psychological stresses. Most of the participants rated the RPE at 18 immediately after the simulation. The YoSFS[5] protocol revealed high similarity with previous studies (15,24). Thus, the YoSFS[5] results indicated a strong fatigue effect on young soccer players, which could be attributed to similarities in the protocol and match play situation components.

This simulation's external load was not verified with a match activity profile because it is a short-duration, high-intensity activity; thus, it differs from a soccer match, which lasts 90 minutes. Activities such as ball passing, ball heading, ball shooting, and sprinting with a ball were included in the YoSFS[5], as they typically occur in a soccer match. Therefore, these activities and the load may be valid, as they were consistent with those in the simulation model in Bossuyt et al. The YoSFS[5] was verified by experts (exercise specialists and soccer sports trainers) (15).

YoSFS[5] Measurement Reliability

The relative reliability of the variables ranged from satisfactory to excellent (ICC > 0.70) for HR, RPE, and CMJ. Thus, this simulation was reproducible, with a 95% limit of agreement. The findings of this study suggested that the YoSFS[5] was a reliable fatigue simulation tool that was consistent with previous studies (28,35,49). The absolute reliability of the YoSFS[5] was measured using SEM and reported as CV (%). The values of the SEM in the mean HR (1.01 beat/min), RPE (1.03), and CMJ (1.09 cm) are indicators that clinicians can interpret to detect measurement errors but not improvements in players during training (43,44). The present study found that the CV of all the variables was below 10%, which is regarded as an acceptable level of reliability, with HR, RPE, and CMJ as 0.9%, 5.5%, and 8.35%, respectively. The HR in our study showed satisfactory absolute reliability, which was consistent with previous studies (15,35,43). Meanwhile, the RPE and CMJ also demonstrated significant satisfactory relative and absolute reliability similar to previous studies (15,49). These findings may indicate that HR, RPE, and CMJ can be used as fatigue indicators in fatigue simulations owing to their low variability.

However, this study has several limitations that must be acknowledged. First is, this study was conducted in the laboratory with the normal floor surface. It is not replicate the normal soccer environment, which is grass or turf surface. Second, this study did not determine and verify the reaction of the external load with that in other studies and soccer match plays. Another limitation is that this study recruited only young recreational soccer players. Thus, this study's findings cannot be generalized to elite young or adult soccer players. Finally, in this study, we measured neuromuscular (CMJ), psychophysiological (RPE), and metabolic (HR) changes as indicators of fatigue. These measures are not the gold standards in fatigue measurement. It is good for future studies to conduct reliability studies on this simulation on the grass or turf surface. In addition combination of HR, RPE, CMJ, with lactate acid can be used in future research, as lactate acid is the gold standard for predicting fatigue.

CONCLUSION

In conclusion, the YoSFS[5] is a valid and reliable tool for replicating the fatigue effect in young soccer players. Short-duration, high-intensity simulation involving certain soccer activities may differ from physiological processes triggered during long-duration match plays. However, the YoSFS[5] is a valid instrument compared with the SAFT[5] and youth soccer matches. The relative and absolute reliability analyses show that the YoSFS[5] demonstrates satisfactory-to-excellent reliability. Therefore, the simulation may be suitable for inducing fatigue among young soccer players and thus can be used as an assessment tool for evaluating the risk of injury in screening and return to play assessment.

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REFERENCES

1. Atan SA, Foskett A, Ali A. Special Populations : Issues and Considerations in Youth Soccer Match Analysis. 2014;4(3):103–14.
2. Koutures CG, Gregory AJM. Injuries in youth soccer. Pediatrics. 2010;125(2):410–4.
3. Faude O, RuЯler R, Junge A. Football injuries in children and adolescent players: Are there clues for prevention? Sport Med. 2013;43(9):819–37.
4. Smith MR, Zeuwts L, Lenoir M, Hens N, De Jong LMS, Coutts AJ. Mental fatigue impairs soccer-

specific decision-making skill. 2016;34(14):1297–304.
5. Difiori JP, Benjamin HJ, Brenner JS, Gregory A, Jayanthi N, Landry GL, et al. Overuse injuries and burnout in youth sports: A position statement from the American Medical Society for Sports Medicine. Br J Sports Med. 2014;48(4):287–8.
6. Read PJ, Oliver JL, De Ste Croix MBA, Myer GD, Lloyd RS. Assessment of injury risk factors in male youth soccer players. Strength Cond J. 2016;38(1):12–21.
7. Rampinini E, Bosio A, Ferraresi I, Petruolo A, Morelli A, Sassi A. Match-related fatigue in soccer players. Med Sci Sport Exerc [Internet]. 2011;43(11):2161–70. Available from: http://ovidsp.ovid.com/ovidweb. cgi?T= JS&CSC= Y&NEWS =N&PAGE= fulltext&D =medl &AN= 21502891
8. Rahnama N, Reilly T, Lees A. Muscle fatigue induced by exercise simulating the work rate of competitive soccer Muscle fatigue induced by exercise simulating the work rate of competitive soccer. J Sports Sci. 2003;21:933–42.
9. Mohr M, Krustrup P, Bangsbo J. Fatigue in soccer: A brief review. J Sports Sci. 2005;23(6):593–9.
10. Philippaerts RM, Vaeyens R, Janssens M, Van Renterghem B, Matthys D, Craen R, et al. The relationship between peak height velocity and physical performance in youth soccer players. J Sports Sci. 2006;24(3):221–30.
11. Meeusen R, Watson P, Hasegawa H, Roelands B. Central Fatigue: The Serotonin Hypothesis and Beyond. Sport Med. 2006;36(10):881–909.
12. Mclean SG, Felin RE, Suedekum N, Calabrese G, Passerallo A, Joy S. Impact of Fatigue on Gender-Based High-Risk Landing Strategies. Med Sci Sport Exerc. 2007;39(3):502–14.
13. Mccall A, Carling C, Davison M, Nedelec M, Gall F Le, Berthoin S, et al. Injury risk factors , screening tests and preventative strategies : a systematic review of the evidence that underpins the perceptions and practices of 44 football (soccer) teams from various premier leagues. Br J Sports Med. 2015;49:583–9.
14. Small K, McNaughton L, Greig M, Lovell R. The effects of multidirectional soccer-specific fatigue on markers of hamstring injury risk. J Sci Med Sport. 2010;13(1):120–5.
15. Bossuyt FM, Garcнa-Pinillos F, Raja Azidin RMF, Vanrenterghem J, Robinson MA. The Utility of a High-intensity Exercise Protocol to Prospectively Assess ACL Injury Risk. Int J Sports Med. 2015;37(2):125–33.
16. Maffulli N, Longo UG, Gougoulias N, Loppini M, Denaro V. Long-term health outcomes of youth sports injuries. Br J Sports Med. 2010;44(1):21–5.
17. Waldйn M, Hдgglund M, Magnusson H, Ekstrand J. ACL injuriesWaldйn, M., Hдgglund, M., Magnusson, H., & Ekstrand, J. (2016). ACL injuries in men's professional football: a 15-year prospective study on time trends and return-to-play rates reveals only 65% of players still play at the top level 3 years af. Br J Sports Med [Internet]. 2016;50(12):744–50. Available from: http://www.ncbi.nlm.nih.gov/pubmed/27034129
18. Rekik RN, Tabben M, Eirale C, Landreau P, Bouras R, Wilson MG, et al. ACL injury incidence, severity and patterns in professional male soccer players in a Middle Eastern league. BMJ Open Sport Exerc Med. 2018;4(1):1–5.
19. Webster KE, Myer GD. Risk of Secondary Injury in Younger Athletes After Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis. Am J Sport Med. 2016;44(7):1861–76.
20. Devlin L. Recurrent Posterior Thigh Symptoms Detrimental to Performance in Rugby Union Predisposing Factors. Sport Med. 2000;29(4):273–87.
21. Sangnier S, Tourny-Chollet C. Comparison of the decrease in strength between hamstrings and quadriceps during isokinetic fatigue testing in semiprofessional soccer players. Int J Sports Med. 2007;28(11):952–7.
22. Greig M, Walker-Johnson C. The influence of soccer-specific fatigue on functional stability. Phys Ther Sport [Internet]. 2007;8(4):185–90. Available from: http://www.sciencedirect.com/science/article/pii/S1466853X07000296
23. Oliver JL, Armstrong N, Williams CA. Reliability and validity of a soccer-specific test of prolonged repeated-sprint ability. Int J Sports Physiol Perform. 2007;2(2):137–49.
24. Thatcher R, Batterham M. Development and Validation of a Sport Specific Exercise Protocol for Elite Youth Soccer Player.Pdf. J Sports Med Phys Fitness. 2004;44(15–22).
25. van Melick N, van Rijn L, Nijhuis-van der Sanden MWG, Hoogeboom TJ, van Cingel REH. Fatigue affects quality of movement more in ACL-reconstructed soccer players than in healthy soccer players. Knee Surgery, Sport Traumatol Arthrosc [Internet]. 2019;27(2):549–55. Available from: http://dx.doi.org/10.1007/s00167-018-5149-2
26. Barrett S, Guard A, Federation USS, Lovell R. Elite-youth and university-level versions of SAFT 90 simulate the internal and external loads of competitive soccer. Sci Footb VII Proc Seventh World Congr Sci Footb. 2014;(2013):95–100.
27. Lovell K, Knapper B, Small K. Physiological responses to SAFT90: a new soccer-specific match simulation. Coach Sport Sci. 2008;3:46–67.
28. Nicholas CW, Frank E.Nuttall, Williams C. The Loughborough Intermittent Shuttle Test : A field test that simulates the activity pattern of soccer. J Sports Sci. 2000;18:97–104.
29. Russell M, Benton D, Kingsley M. The effects of fatigue on soccer skills performed during a soccer match simulation. Int J Sports Physiol Perform. 2011;6(2):221–33.

30. De Ste Croix MBA, Priestley AM, Lloyd RS, Oliver JL, Croix MBADS, Priestley AM, et al. ACL injury risk in elite female youth soccer: Changes in neuromuscular control of the knee following soccer-specific fatigue. Scand J Med Sci Sport. 2015;25(5):e531–8.
31. Harper LD, Briggs MA, McNamee G, West DJ, Kilduff LP, Stevenson E, et al. Physiological and performance effects of carbohydrate gels consumed prior to the extra-time period of prolonged simulated soccer match-play. J Sci Med Sport [Internet]. 2016;19(6):509–14. Available from: http://dx.doi.org/10.1016/j.jsams.2015.06.009
32. Russell M, Kingsley MIC. Changes in Acid-Base Balance During Simulated Soccer Match Play. J Strength Cond Res. 2012;26(9):2593–9.
33. Oliver J, Armstrong N, Williams C. Changes in jump performance and muscle activity following soccer-specific exercise. J Sports Sci. 2008;26(2):141–8.
34. Oliver JL, De Ste Croix MBA, Lloyd RS, Williams CA. Altered neuromuscular control of leg stiffness following soccer-specific exercise. Eur J Appl Physiol. 2014;114(11):2241–9.
35. Aldous J, Akubat I, Chrismas B, Mauger A. The Reliability and Validity of a Soccer-Specific Nonmotorised Treadmill Simulation (Intermittent Soccer Performance Test). J Strength Cond Res. 2014;26(7):1971–80.
36. Bishop D, Spencer M, Duffield R, Lawrence S. The validity of Repeatde Sprint Ability test. J Sci Med Sport. 2001;4(1):19–29.
37. Arifin WN. A Web-based Sample Size Calculator for Reliability Studies. Educ Med J. 2018;10(3):67–76.
38. Dellal A, Wong DP, Moalla W, Chamari K. Physical and technical activity of soccer players in the French first league- with special reference to their playing position. Int Sport J. 2010;11(2).
39. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-Based Training Load in Soccer. Med Sci Sport Exerc. 2004;36(6):1042–7.
40. Steib S, Zech A, Hentschke C, Pfeifer K. Fatigue-induced alterations of static and dynamic postural control in athletes with a history of ankle sprain. J Athl Train. 2013;48(2):203–8.
41. Balsalobre-fern6ndez C, Glaister M, Lockey RA, Glaister M, Lockey RA, Balsalobre-fern6ndez C, et al. The validity and reliability of an iPhone app for measuring vertical jump performance. J Sports Sci [Internet]. 2016;33(15):1574–9. Available from: http://dx.doi.org/10.1080/02640414.2014.996184
42. Logan S, Hunter I, Hopkins JT, Feland JB, Parcell AC. Ground reaction force differences between running shoes, racing flats, and distance spikes in runners. J Sport Sci Med. 2010;9(1):147–53.
43. Hůlka K, Lehnert M, Bělka J. Reliability and validity of a basketball-specific fatigue protocol simulating match load. Acta Gymnica [Internet]. 2017;47(2):92–8. Available from: https://doi.org/10.5507/ag.2017.009
44. Hopkins WG. Measures of Reliability in Sports Medicine and Science. Sport Med. 2000;30(1):1–15.
45. Fleiss J. Reliability of measurement. In: The design and analysis of clinical experiments. Wiley, New York. 1986;1–32.
46. Atkinson G, Nevill AM. Statistical Methods For Assessing Measurement Error (Reliability) in Variables Relevant to Sports Medicine. Sport Med. 1998;26(4):217–38.
47. Randers MB, Andersen TB, Rasmussen LS, Larsen MN, Krustrup P. Effect of game format on heart rate , activity profile , and player. Scand J Med Sci Sports. 2014;24(Supplement 1):17–26.
48. Bishop DJ. Fatigue Mechanisms Limiting Exercise Performance Fatigue during intermittent-sprint exercise. Clin Exp Pharmacol Physiol. 2012;39:836–41.
49. Slinde F, Suber C, Suber L, N CEE, Ulla S. Test–Retest Reliability of Three Different Countermovement Jumping Tests. J ofStrength Cond Res. 2008;22(2):640–4.