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ORIGINAL ARTICLE
EXERCISE PHYSIOLOGY AND BIOMECHANICS

Validity of simple field tests as indicators of elite female field hockey match performance

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ABSTRACT

BACKGROUND: Due to the change in field hockey match format, the need exits for research to determine whether current fitness test are still valid indicators of match performance. This study aimed to determine the direct validity of the 5-m multistage shuttle test (5-m MST) and Yo-Yo Intermittent recovery level 1 test (Yo-Yo IR1) by correlating their results with external load measures in international field hockey matches.
METHODS: Nineteen female field hockey players completed the 5-m MST and Yo-Yo IR1 before nine matches.
RESULTS: Players covered mean distances of 750.3 m±19.6 m (5-m MST) and 1649.7 m±277.6 m (Yo-Yo IR1). Average relative distance, relative player load, and high-intensity activity during matches were 107.8±16.3 m/min, 10.3±1.4 AU/min, and 10.0±3.0%, respectively. The 5-m MST showed small to moderate significant ($P<0.05$; $r=0.21$-0.5) correlations with relative distance and high-intensity activity, while the Yo-Yo IR1 only had a small negative significant ($P<0.05$; $r=-0.27$) correlation with high-intensity activity. Strong correlations ($r>0.51$) were found between the 5-m MST and Yo-Yo IR1.
CONCLUSIONS: The tests demonstrated low direct validity for current field hockey matches due to weak relationships with relative load and running performance. Additionally, the strong correlation between the Yo-Yo IR1 and 5-m MST suggests that both tests may not be necessary to assess match readiness. Coaches should consider using better-validated fitness tests for this population and sport.

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KEY WORDS: Hockey; Workload; Physical fitness; Anaerobic threshold.

Field hockey is described as an intermittent team sport, based on the physical and physiological demands experienced by players during training and match-play.[1-3] However, with a change in the format of international field hockey matches from two, 35-minute halves, to four, 15-minute quarters (Qtrs), matches are marked by greater intensities with differences in various external- (relative distance [RD] and low- to high-intensity activities [HIA]) and internal (heart rate [HR]) match loads reported.[4-7] The increase in intensity highlights the importance of a well-developed aerobic- and anaerobic capacity to sustain repeated HIA or repeated sprint ability (RSA).[2, 3, 8] To assess this essential component, the 5-meter multistage shuttle- (5-m MST) and Yo-Yo intermittent recovery level 1 (Yo-Yo IR1) tests have been recommended to effectively assess a player's ability to repeatedly perform HIA.[9-12] Moreover, prior research have demonstrated the validity of these tests by demonstrating a good association between the results of these fitness tests and match load for several team sports, including field hockey.[8, 9, 13, 14] However, because the study[9] was conducted on the previous match format under different match loads. Given that the demands of field hockey have changed and that the comparability of field tests with match performance is based on the old format, re-investigation of the validity of these test findings as indications of match performance may be necessary.

Literature examining the relationship between the results of the 5-m MST with match load under the previous

format showed a significant relationship (r=0.63) between the 5-m MST with TD and RD covered during female field hockey match-play.[9] Also, studies pertaining to the relationship between Yo-Yo IR1 test results and match load for female hockey players showed smaller relationships, specifically for running performance (walking: r=0.39; jogging: r=0.26; high-intensity running [HIR]: r=0.54; and sprinting r=0.36).[14] Although the relationship is smaller than in other intermittent team sports, players in Harry and Booysen's[14] study covered less distance (930 m) during the Yo-Yo IR1 test compared to players competing at similar and/or higher standards (1500-2000 m), implying lower fitness levels, which could influence the relationship.

Since rolling substitutions affect the intensity and absolute load that players perform, relative distance covered (RD) is thought to be a more accurate indicator of match intensity than total distance covered.[3, 15] In this regard, players cover greater RD (128-147 m/min) and HIA distances in the current format than in the previous format (109-128 m/min), indicating higher match intensities.[1, 3, 5, 6, 16-18] Furthermore, findings on player load (PL) (measured in arbitrary units [AU]), which calculates match load through measures of accelerations, decelerations, changes in direction, collisions, and repeated HIA rather than running distance,[19-21] show comparable relative player loads (RPL) between match formats (11.2-11.3 AU/min).[3] As a result of greater match intensities reported under the current format, the relationship between selected fitness tests with match loads could be different.

Direct validity is determined when findings from a field fitness test can be directly compared to players' actual physical qualities during competitive matches.[9] It is essential to establish direct validity for field tests to ensure that they are meaningful and helpful instruments for measuring an athlete's capabilities and future performance in real-world competition. With the change in match format and higher intensities reported by recent research, a re-investigation of the applicability of field tests to be relevant in terms of match performance is required. By proving a significant and meaningful association between field test results and match performance, practitioners can use these field tests with confidence to make informed decisions for team selection and performance monitoring. Therefore, considering this, the purpose of this study was to determine the direct validity of the 5-m MST and Yo-Yo IR1 tests by examining the correlations between these tests' results and selected external load measures during field hockey matches.

Materials and methods

Participants

The participants in the study were 19 international female field hockey players (age: 24.9±3.7 years, height: 166.3±4.2 cm, body mass: 61.7±4.1 kg) who competed in nine competitive matches at an international tournament. According to the official FIH rankings at the time of data collection, the team was ranked 14th in the world. These tests were also part of the yearly training camp testing, so all players were familiar with them. Only data from players who completed the 5-m MST and Yo-Yo IR1 tests two weeks before the start of the international tournament were retained. All players were familiar with the 5-m MST and Yo-Yo IR1 tests as they formed part of all training camp testing protocols. The Health Research Ethics Committee of the university where the study was conducted provided ethical approval prior to data collection (NWU-00965-19-A1-01). Before beginning the assessment procedures, all players provided written informed consent.

Five-meter shuttle run test

The 5-m MST was used according to the method previously described by Boddington *et al.*[9] to measure RSA. The layout of the 5-m MST consisted of six cones which were placed 5 m apart in a straight line to cover a TD of 25 m. Players started the test behind the first cone and upon an auditory signal, sprinted 5 m to the second cone and then returned to the first cone. Players then sprinted 10 m to the third cone and back to the first cone. This sprint pattern continued with players sprinting back and forth until a period of 30-seconds had elapsed. Players were given a 35-second rest period between bouts and they repeated this activity six times (six bouts). Time was kept on a hand-held stopwatch. The distance covered by each player was approximated to the nearest 2.5 m during each 30-second shuttle. During the execution of the RSA test, players were instructed not to pace themselves but to perform the test with maximal effort throughout. Variables retained for analysis include RSA_{total} (m), RSA_{peak} (m), Fatigue Index (FI) and percentage decrement (RSA_{dec}), The formulae to calculate FI and RSA_{dec} is as follows:[22]

$$FI(\%) = 100 \times \frac{(RSA_{peak} - RSA_{min})}{RSA_{peak}}$$

$$RSA_{dec}(\%) = \left(\frac{RSA_{total}}{RSA_{peak} \times \text{number of sprints}} - 1 \right) \times 100$$

FI determines the player's ability to resist fatigue by looking at the percentage decline between the best (RSA_{peak}) and worst (RSA_{min}) sprint. On the other hand, RSA_{dec} compares the actual performance (RSA_{total}) of the player to the ideal performance (*i.e.* referring to the best sprint being maintained throughout the test).[22-25]

Yo-Yo Intermittent recovery test level 1

The Yo-Yo IR1 test, as previously described by Bangsbo *et al.*,[8] was used to assess the aerobic capacity of each player. Participants were required to touch the marked lines at either end of the 20-m marks with one foot when the signal sounded. After each 40-m interval, players were given a 10-second active recovery period, during which they had to walk back and forth over a 5-m distance. The initial running speed at which the test started was 10 km/h, after which the speed progressively increased. A verbal warning was given to players if they did not reach the line by the time the first beep-tone sounded. The test was terminated for players who failed to reach the line two consecutive times within the given period or if they stopped participating voluntarily. The maximal distance in meters (Yo-Yo $IR1_{total}$) covered by each player was retained for analysis.

Match activity

Activity profiles of all players (starting line-up and bench) were measured with the Catapult Sports MinimaxX S4 V4.0 10-Hz Global Positioning Systems (GPS) equipped with a 100-Hz accelerometer (Catapult Innovations, Melbourne, Australia). Bench periods were excluded from the analysis. The validity and reliability of these devices have previously been verified.[26-28] GPS units were turned on and left idle for 10 minutes before pre-match warm-ups to allow for the location of satellites. The GPS units were fitted to the upper back of each player using a harness supplied by the manufacturer. Locomotor categories used were adapted from those previously used by Macutkiewicz and Sunderland[18] and McGuinness *et al.*[15] for international female field hockey players: low- (LIA) (0-2.2 m/s); moderate- (MIA) (2.3-4.4 m/s); and high- (HIA) (≥4.5 m/s) intensity activity. For a movement to be recorded as an effort, players had to maintain specific movement velocities for at least 0.5 seconds. PL was determined by software (described below) using the following formula: $(a_{y1} - a_{y-1})^2 + (a_{x1} - a_{x-1})^2 + (a_{z1} - a_{z-1})$,[2] where a_y refer to anteroposterior, a_x to mediolateral, and a_z to vertical acceleration. Data were normalized to distance per minute (m/min) and RPL (AU/min) to account for differences in playing time and rolling substitutions. The mean horizontal dilution of precision (HDOP) and satellite availability during the tournament was 0.93±0.05 and 10.9±0.4, respectively. The data were further divided into Qtrs 1-4. GPS Doppler data was used during the analysis of the GPS-related variables after an intelligent motion filter was applied.

Statistical analysis

The Statistical Package for Social Sciences (IBM SPSS® Statistics v. 27) was used for statistical analysis. Descriptive statistics (mean and standard deviation) were calculated for all variables. A Shapiro-Wilk Test confirmed that the data was not normally distributed, and therefore a bivariate (Spearman's rho) correlation test was used to determine the direction and strength of the relationship between the results of selected fitness tests and match load. The level of statistical significance (P value) was set at ≤0.05. The correlation coefficients classification used to describe the results were: r≤0.1 (trivial); r=0.11-0.30 (small); r=0.31-0.50 (moderate); r=0.51-0.70 (large); r=0.71-0.90 (very large); and r=0.91-1.0 (nearly perfect).[27]

Results

The RSA_{total} and RSA_{peak} covered during the 5-m MST were 750.3±19.6 m and 133.9±3.0 m, respectively. Players had a mean FI% of 11.3±4.2% whereas the RSA_{dec} was 6.5±2.5%. With regards to distance covered during the Yo-Yo IR1 test, players covered a mean distance of 1649.7±277.6 m. The external match load for international female field hockey players can be viewed in Table I. The

TABLE I.—*Descriptive data (mean±SD) of external match loads for elite female field hockey players.*

Variable	Total (N.=135)	Qtr 1 (N.=129)	Qtr 2 (N.=132)	Qtr 3 (N.=131)	Qtr 4 (N.=128)
RD (m/min)	107.8±16.3	114.6±14.5	107.9±17.4	104.9±19.4	103.8±14.9
RPL (AU/min)	10.3±1.4	11.1±1.6	10.4±2.0	10.0±2.1	9.9±1.7
LIA (%)	41.3±4.4	39.5±5.4	40.8±5.7	43.1±8.2	42.7±7.6
MIA (%)	47.9±3.9	50.4±5.1	48.2±5.6	47.0±7.5	45.5±7.7
HIA (%)	10.0±3.0	9.2±3.8	10.1±4.4	9.2±4.4	10.2±4.4

RD: relative distance (m/min); RPL: relative player load (AU/min); LIA-, MIA-, HIA%: percentage of distance covered at low- (LIA), moderate- (MIA), and high-intensity (HIA); N.: number of files analyzed; Qtr: quarter.

mean RD covered during match-play was 107.8±16.3 m/min. Players covered a RPL, LIA%, MIA%, and HIA% of 10.3±1.4 AU/min, 41.3±4.4%, 47.9±3.9%, and 10.0±3.0% throughout match-play, respectively.

Figure 1 depicts the scatterplots of significant correlations between the fitness test results in relation to match performance. In terms of RSA_{total} and match load, a significant (P<0.05) small positive correlation for RD (r=0.21), which was covered throughout match-play, was observed. RSA_{peak} had significant positive correlations with RD (r=0.25) and HIA% (r=0.22). Positive correlations (P<0.05) were found for FI% and RPL (r=0.21) and also for HIA% (r=0.40). Furthermore, RSA_{dec} showed a significant positive correlation with HIA% (r=0.29). Finally, the Yo-Yo IR1 test results showed a negative correlation with HIA% (r=-0.27). Also, worth noting are the

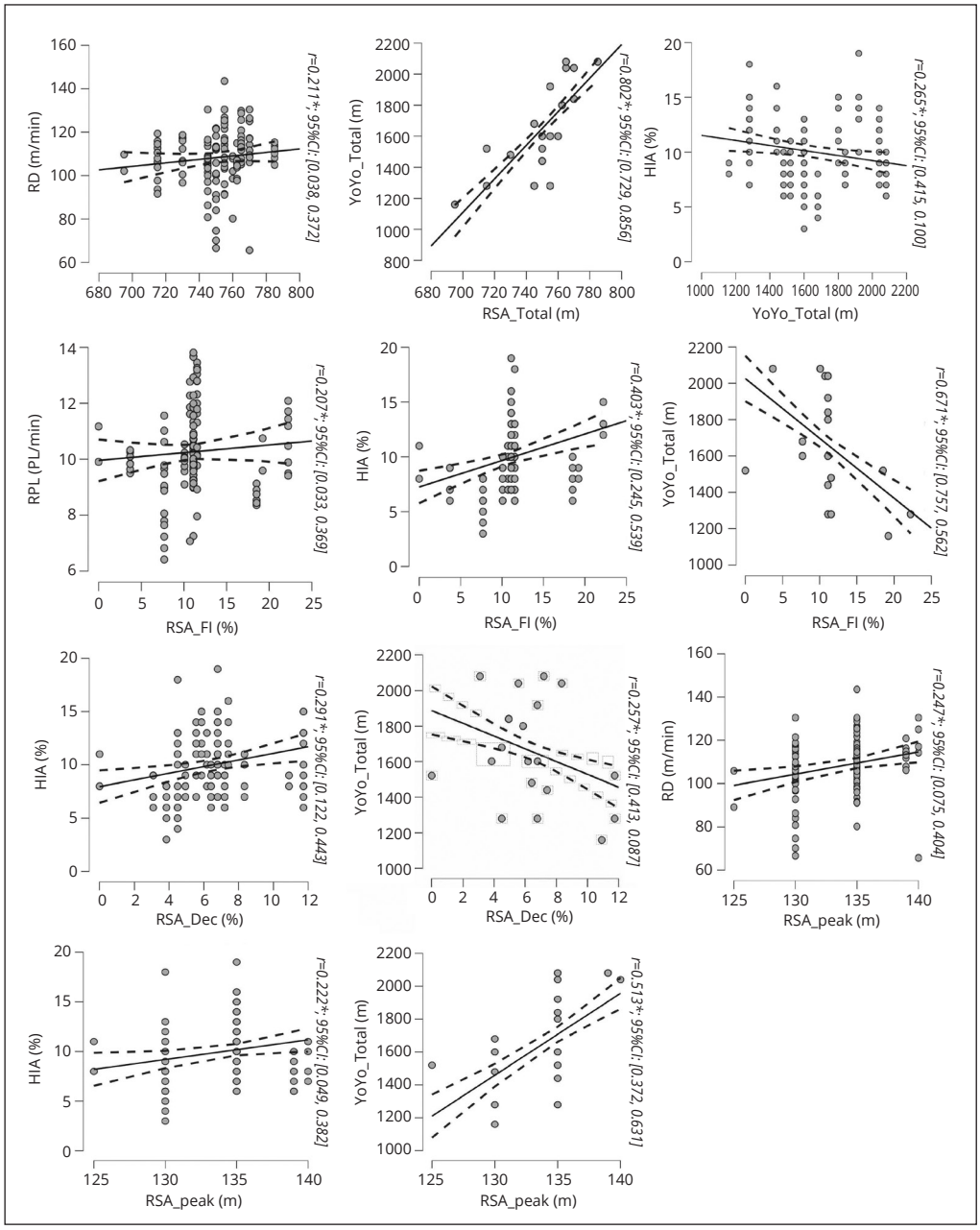

Figure 1.—Scatter plots for significant correlations between fitness test results and match performance variables.
Dec: deceleration; FI: Fatigue Index; HIA: high-intensity activity; RD: relative distance; RPL: relative playerload; RSA: repeated sprint ability; Yo-Yo_total: total distance covered during Yo-Yo test. *P<0.05.

large to very large correlations between the Yo-Yo IR1 and RSA test results. Several significant correlations were also found between the Yo-Yo IR1 and RSA results.

Discussion

The main aim of this study was to determine the direct validity of the 5-m MST and Yo-Yo IR1 tests by examining the correlations between these tests' results and selected external load measures during international field hockey matches. By proving a significant correlation between field test outcomes and in-game performance, practitioners can reliably use these tests to identify gifted athletes or gauge a players' level of competitive play preparedness. The main findings of this study showed small to moderate significant relationships between the 5-m MST with several match load variables, with the Yo-Yo IR1 results showing only a small significant relationship with HIA. Although it was not the aim of the study, the large to very large correlation between the 5-m MST and Yo-Yo IR1 results should be noted.

Data from the current study show that players covered an RSA_{total} and RSA_{peak} distance of 750.3 m and 133.9 m during the performance of the 5-m MST, respectively, which is greater than those previously reported for club- and regional level female field hockey players (RSA_{total}: 661-690 m).[9, 29] Higher values from the current study could highlight greater training demands for players competing at an international level. Findings by Boddington *et al.*[9] suggested that greater distances covered during the 5-m MST would directly correlate (r=0.63) to greater distances covered during match-play and vice-versa. However, results from this study show a small positive relationship between the results of the 5-m MST (RSA_{total}, RSA_{peak}) and RD (r=0.21-0.25) and HIA (r=0.22). These results suggest that performance in the 5-m MST is only slightly related to international match performance under the current format.

Another appealing metric, which refers to the drop-off in performance during 5-m MST is FI% and RSA_{dec}. The mean FI% and RSA_{dec} in this study was 11.3% and 6.5%, respectively. This falls within the range of 5-15% for fatigue development in running protocols reported by Girard *et al.*[22] Furthermore, small-to-moderate positive relationship between FI% and RPL and HIA was found with RSA_{dec} showing a small positive correlation with HIA. The findings suggest that the higher the fatigue-development measures, the higher the RPL and HIA during match-play. This positive relationship could be explained through possible limitations in the use of FI% during the 5-m MST. While valuable, researchers warn that findings on FI% should be viewed with caution as results could be misleading.[28, 29] To calculate a decline in performance, players are instructed not to pace themselves but complete the test with maximum effort, however if they do not perform at maximum capacity, the FI% metric will not reflect fatigue accurately. Moreover, the unpredictable nature of field hockey, sprinting can occur at random times, and across various distances and velocities, with differing rest intervals.[30] Therefore, the 5-m MST may fail to account for differences in rest intervals and running performance (LIA, MIA and HIA) during match-play. Furthermore, the possibility of pacing strategies used during matches should also be considered. This notion is supported by our data, which show that despite reductions in relative load (possibly fatigue), players covered more distance in the form of HIA during Qtr 4 compared to Qtr 1, possibly indicating pacing, which could have resulted in the positive relationship. It is also suggested that RSA_{dec} is superior to FI%, because FI% only considers the best and worst sprints whereas RSA_{dec} takes all the sprint bouts into account.[22] In conclusion, while the 5-m MST was described to significantly correlate with match load under the previous format, findings from the current study show smaller but still significant relationships with match load.

In this study players covered a mean distance of 1649.7 m during the Yo-Yo IR1 test, which is comparable to the distances reported (1500-2020 m) for national- and international-level female field hockey players.[12, 15] When the relationship with match load is considered, our study's data revealed no significant relationships with relative load (RD and RPL). Furthermore, when running performance (LIA, MIA, and HIA) is considered, previous research on female field hockey players revealed a small-to-moderate-sized positive relationship with distances covered during walking (r=0.39), jogging (r=0.26), HIR (r=0.54), and sprinting (r=0.36) during match-play.[14] However, in our study only a small negative relationship was found between the result of the Yo-Yo IR1 test and HIA (r=-0.27). This means that greater distances covered during the Yo-Yo IR1 test would result in less HIA distance covered during match-play. This negative relationship could highlight limitations within the Yo-Yo IR1 test. Players from the current study covered the largest portion (0-1400 m = level 5.1-16.8) of the Yo-Yo IR1 test at low- to moderate intensities (0-4.4 m/s), with the remaining distance (249.7 m = level >17.1) covered in the form of HIA (>4.5 m/s). Therefore, accumulative fatigue incurred during lev-

els 5.1-16.8, could adversely affect a player's ability to perform HIA during ensuing levels (level >17.1), which could explain the small relationship between HIA covered during match-play and lower HIA covered during the Yo-Yo IR1 test. Furthermore, active recovery is necessary between levels during the Yo-Yo IR1 test, whereas in field hockey, although there are moments of active recovery, there are also rolling substitutions where players sit on the bench and experience passive recovery. Differences in recovery tactics will thus have a direct impact on fatigue onset and may explain the disparity in results.[22] Finally, data from this study suggest that the results of the Yo-Yo IR1 test may not be relevant to current relative match load and running performance, casting doubt on the use of this test to assess a player's readiness to meet match demands.

The significant relationships between the 5-m MST and Yo-Yo IR1 results were intriguing, even though they were not the focus of this study. Yo-Yo $IR1_{Total}$ had significant positive correlations with RSA_{Total} (r=0.80) and RSA_{peak} (r=0.51) and significant negative correlations with FI% (r=0.67) and RSA_{dec} (r=0.25). These findings imply that both tests may not be necessary to assess players' match readiness and given the weak relationships between Yo-Yo IR1 results and match performance, the 5-m MST would be a better choice for elite female field hockey players.

Limitations of the study

Although the findings form this study provides novel information regarding the applicability of these tests and match performance under the current format, the results might not be generalizable as it only assessed the performance of one team. Furthermore, some matches were played on consecutive days with the possibility of accumulative fatigue being present. This might affect the association between fitness tests and match performance. Although major field hockey tournaments often play competitive matches on consecutive days or in quick succession, future studies should also measure these associations between field tests and match performance where sufficient recovery times between matches are allowed.

Conclusions

This study showed small to moderate significant relationships between the 5-m MST with several match load variables, with the Yo-Yo IR1 results showing only a small significant relationship with HIA. The lack of strong relationships with relative load and running performance suggest that these tests may lack direct validity under the current field hockey match format. Furthermore, the strong relationship between the Yo-Yo IR1 test and 5-m MST test results suggest that the need for both tests to evaluate players' match readiness may not be necessary. The 5-m MST is however superior to the Yo-Yo IR1 due to more significant relationships with match performance. We do however suggest that future studies examine different fitness tests which might have a greater direct validity with female field hockey match-play performance under the current format.

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Conflicts of interest
The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions
All authors read and approved the final version of the manuscript.

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