Abstract

Objective: The aim of this study was to verify if the yo-yo intermittent recovery test (level 2) (yo-yo IR2) score is linked to Australian Football performance through match exercise intensity.

Method: Twenty-one data sets were recorded from nine individual players that completed the yo-yo IR2, and played an Australian Football League match in the first five rounds of the 2010 season wearing a global positioning system (GPS) unit. Simple mediation modelling was used to analyse the inter-relationship between yo-yo IR2 score, match exercise intensity and Australian Football performance. Playing position and experience were also incorporated into the model to identify conditional affects.

Results: A significant direct relationship was observed between yo-yo IR2 and number of ball disposals ($p < 0.1$) and a significant indirect relationship was observed between yo-yo IR2 and number of ball disposals through distance travelled at high intensity (HIR $m \cdot min^{-1}$) ($p < 0.1$). Moderation analysis showed that playing position affected the relationship between of yo-yo IR2 and HIR $m \cdot min^{-1}$ ($p < 0.1$) and HIR $m \cdot min^{-1}$ and total ball disposals ($p < 0.1$). Playing experience also significantly affected the relationship between HIR $m \cdot min^{-1}$ and total ball disposals.

Conclusions: This study is the first to identify the effects of yo-yo IR2 on total ball disposals through HIR $m \cdot min^{-1}$ performed during Australian Football matches and that playing position and playing experience affect these interactions.

Key Words: Global Positioning System, Yo-Yo intermittent recovery test, team sport, match exercise intensity.

Introduction

Due to advances in player tracking technology, recent studies examining the match demands of top level team sports have provided an improved understanding of the requirements of competition[1, 2]. In addition, recent studies in soccer have shown that training physical capacities (such as endurance qualities) can positively impact on match exercise intensity[3, 4]. However, at present there is little empirical knowledge about the contribution of specific physical capacities to Australian Football performance, or if match exercise intensity mediates this relationship.

In a recent conceptual model of factors affecting soccer performance, Impellizzeri and Marcora[5] suggested that tactical, technical and physical performance were relevant constructs of team ranking. It was also reported that high intensity activity (match exercise intensity) is a causal indicator of overall physical performance, and that valid field tests provide an indication of the capacity of the athlete to produce high intensity activity[5]. This model suggests that match exercise intensity may mediate the effect (i.e. act in a causal sequence between two variables)[6] of physical capacity on performance in soccer. However, further conditional circumstances (e.g. gender, age etc.) may also impact on these relationships. These variables are defined as moderators and can be incorporated into a mediation model[6]. Some studies have identified relationships, exclusively in soccer, between training adaptations and improved physical capacity, improved physical capacity and match exercise intensity, and match exercise intensity and team success[4, 7, 8]. However, a mediation analysis has not yet been conducted to determine if these relationships are linked.

Studies on soccer players have shown that improvements in aerobic endurance are matched with increased distance[8, 9] and increased involvement with the ball[8]. Gains in

these qualities may also improve match exercise intensity and subsequently impact on similar performance variables in Australian Football. In support of this, several studies have shown that higher endurance qualities (i.e. maximal oxygen uptake, yo-yo IR2) and anaerobic qualities (i.e. 5 and 10 m sprint time) components are important for elite Australian Football players[10, 11]. For example, Young et al.[10] found that the yo-yo intermittent recovery (level 2) (yo-yo IR2) was significantly higher in starters compared to non-starters at the start of an Australian Football League (AFL) season. Furthermore, the yo-yo IR2 has been identified to have a strong relationship with high intensity distance travelled in soccer[3, 7]. Together, these studies show that the yo-yo IR2 is a relevant physical capacity test of high intensity intermittent endurance for team sports, suggesting the model of Impellizzeri and Marcoa[5] also applies to Australian Football. Currently, the relationships between yo-yo IR2 performance and physical and playing performance in Australian Football has not been identified.

Therefore, this study aimed to identify: 1) if there is a relationship between yo-yo IR2 score and various performance measures in Australian Football (i.e. ball disposals, player impact score and coaches' rating), 2) if match exercise intensity is a mechanism of the relationship; and, 3) if playing position and playing experience impact on these relationships.

Methods

Forty-six male elite Australian footballers from the same team were invited to participate in this study. The participants had a mean (±SD) stature of 187.6 ±7.3 cm, mass of 86.5 ±8.7 kg and age of 22.3 ±3.3 years. Informed consent was gathered prior

to the commencement of the studies. Ethical approval was obtained by the University Research Ethics Committee (see Appendix A).

Physical capacity (reflected by yo-yo IR2), match exercise intensity (reflected by distance per minute, high intensity distance per minute and summation of accelerations per minute) and match performance (reflected by player impact score based on skill involvement and coaches rating of performance) measures were gathered on participants in a prospective design.

A sample was determined as the same player possessing a yo-yo IR2 score, match exercise intensity and match performance records in the first 5 matches of the season. Of the forty-six footballers invited to participate, only nine recorded at least one sample (ranging 1 – 3) due to test completion, technical error with Global Positioning System units and player selection. A total of 21 samples were obtained. This study predicates Banisters theory that performance is equal to an athlete's capacity subject to fatigue[12]. In order to isolate the impact of physical capacity on performance it was first assume that capacity will not change over the experimental period, this is supported by current literature in elite soccer[13]. Secondly, it was assume that non-functional overreaching is not occurring. As it is outside the scope of this study to measure fatigue we felt it is appropriate to delimit the study to the first 5 matches before cumulative fatigue could potentially confound the results[14].

Participants were required to perform the yo-yo IR2 less than 2 weeks prior to the first match of the regular season. All participants performed the test on the same indoor surface. Each participant had completed this test previously and was familiar with the

procedures. This procedure has been described in detail elsewhere with typical errors ranging from 4.9−10.4% for a variety of sports and standards[15]. After the test, participants underwent one week of their regular training before the commencement of the season.

All participants had their match exercise intensity recorded by portable GPS sampling at 5 Hz (MinimaxX, Team 2.5, Catapult Innovations, Scoresby, Australia). Match exercise intensity and performance measures were gathered for the first five matches of the season, similar to the approach of Young and Prior[16]. Global positioning system data was downloaded post match using manufacture specific software (Logan Plus v. 4.4.0, Scoresby, Australia) for analysis.

Match exercise intensity was only recorded for the on-field playing duration of each participant. In an attempt to reduce the likelihood of reporting artificially high match exercise intensities, GPS samples were only accepted for analysis if the participant played ≥70% of total match time (range 70 – 96% total match time). The exercise intensity variables collected were distance travelled per minute ($m \cdot min^{-1}$) and distance travelled at high intensity per minute (HIR $m \cdot min^{-1}$) where HIR m =distance travelled above 15 $km \cdot h^{-1}$. These variables have been tested for reliability and validity; distance CV =3.6%, validity 3.9% different from reference; high intensity distance (striding and sprinting) CV = 9.0–11.9% (activity dependent), validity range -6.2–4.6% (activity dependent)[17].

The participant's number of skill involvements (ball disposals) and player rank were collected by a commercial statistical analytics company (Champion Data©, South Bank, Australia). The Champion Data© player ranking system is based on the impact

of the player upon the match. A positive rating is allocated to each effective skill execution such as: kicks, handballs, tackles, hit-outs, marks and scoring shots and negative rating is allocated for ineffective skill executions. This rank is similar to the performance measure of Heasman et al.[18] Champion Data© provide a 99% accuracy rate for match statistics[19].

Coaches' perceptions of players performance was collected according to previously described methods[20]. Briefly, five team coaches were asked to rate each participating player's performance on a 1–5 scale (1 = poor performance, to 5 = excellent performance) within an hour after the completion of the match. The sum of the five coaches' votes was used to quantify the player's subjective performance, which encompasses both tactical and technical performance. Internal consistency reliability was conducted after each match and showed a Cronbach's alpha ranging between 0.88 and 0.92 satisfying acceptable reliability (>0.8)[21].

The statistical approach utilised was mediation analysis. The yo-yo IR2 was analysed as the independent variable, while tactical and technical performance measures were individually analysed as dependant variables and match exercise intensity measures as the mediators (see Figure 3.1). Mediation analysis is a process that identifies if a third variable mediates (M = match exercise intensity) an effect between an independent variable (X = yo-yo IR2) and a dependent variable (Y = performance) in a causal sequence[22]. Preacher and Hayes[22] suggest that the causal step approach be used to identify if the variables satisfied the mediation criteria (see Figure 3.1). The causal step approach maintains that in order to satisfy a mediation relationship in the causal sequence, analysis for effects *c, a and b* must be significant, and *ć* must not be

significant. Importantly, *c* is analysed by incorporating the mediator and *ć* is analysed by holding the mediator constant. Thus, if the mediator is in fact a mechanism of the relationship between X and Y, accounting for the mediating variable will weaken the relationship to a non-significant level.

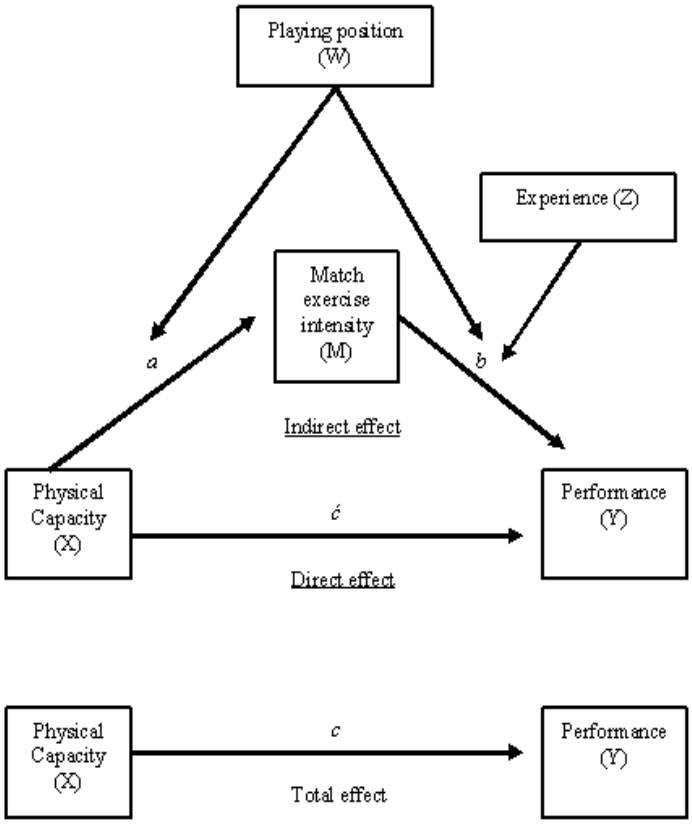


Figure 3.1: A graphical representation of the path of simple mediation analysis adapted from Preacher and Hayes, 2008 pp. 880[22]. X represents the independent variable (physical capacity), Y represents the dependent variable (performance) and M indicates the mediator (match exercise intensity), W represents a moderator for the effect of X→M and X→Y, Z represents the moderator for the effect of M→Y. The effect of X→M is represented by *a*, the effect of M→Y is represented by *b*. The total effect (*c*) of physical capacity (X) on performance (Y) is comprised of the sum of the direct effect (*ć*) and indirect effect (*ab*).

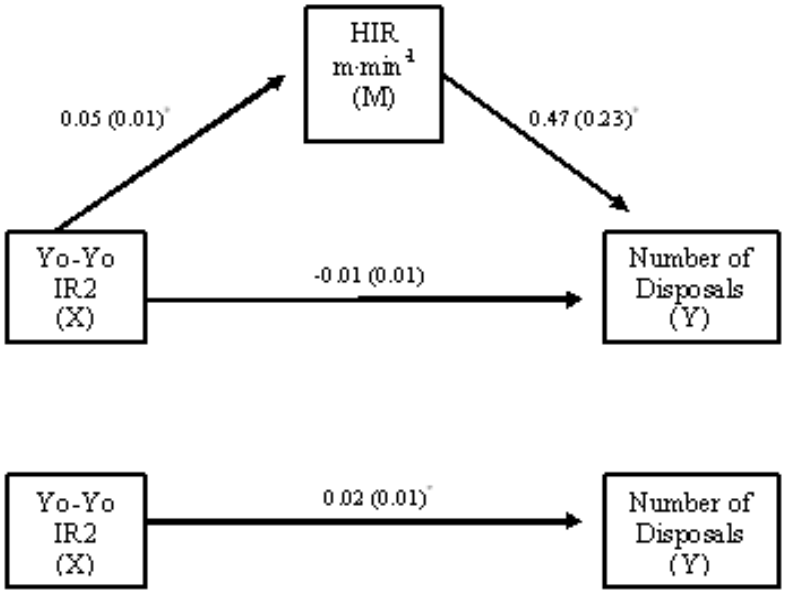
Following satisfaction of a mediation effect, the indirect effect was analysed via the bootstrap method. Bootstrapping is the process whereby a pre-determined number of random selection of the sample is obtained, each data record may be chosen multiple times or never[22]. Bootstrap selection reduced bias and likelihood of type 1 errors, in

this study the bootstrap sample was set at 3000 samples[22]. The indirect effect establishes the degree to which the independent variable and mediator can explain the dependant variable in a causal sequence calculated as $c - \acute{c}$ (See Figure 3.1). Six separate single mediation analyses combinations were performed to isolate the inter-relationships between variables. Mediation was analysed using SPSS v.17 (SPSS Inc., Chicago, USA) using macro and syntax from Preacher and Hayes[22], with significance set at p value of <0.1 as suggested by Batterham and Hopkins[23]. Mediation analysis assumes normality for between variable analyses, therefore all data was deemed normally distributed by a Kolmogorov-Smirnov test before being included into the mediation analysis.

Once a mediation relationship was identified, mediation analysis was repeated under conditional variables (moderators) to ascertain if the relationships were influenced by playing position and/or playing experience. Playing position (W) was separated into two categories of key position (centre half back/forward and full forward/back) and non-key position players (forward/back pockets, half forward/back flanks, wings and midfielders) and was included as a moderator for effects *a* and *b*. Playing experience (Z) was separated into two categories, above and below 50 AFL matches, and was included as a moderator of only effect *b*, as the relationship between yo-yo IR2 and match exercise intensity should not be influenced by experience in elite Australian Football (see Figure 3.1). Mediation-Moderation effect was analysed in SPSS v.17 (SPSS Inc., Chicago, USA) using macro and syntax from Preacher, Rucker and Hayes (moderation-mediation)[24], with a <0.1 significance level.

Results

The mean physical capacity measured by yo-yo IR2 was 1060 ±176 m and match exercise intensity measured by m·min^{-1} and HIR m·min^{-1} was 139.0 ±11.1 m and 40.6 ±9.6 m respectively. Of the six mediation combinations that were tested (1 independent variable, 3 mediators and 3 dependant variables), five failed to meet causal step approach mediation criteria. Significant relationships were found between yo-yo IR2 and all match exercise intensity measures. However, only yo-yo IR2 and total ball disposals showed a significant relationship that was mediated by HIR m·min^{-1} (Figure 3.2). The strength of the mediation indicates that 15.4% of the variation in total ball disposals can be attributed to the indirect effect of yo-yo IR2 and HIR m·min^{-1} (Figure 3.2). Figure 3.2 shows a positive effect of yo-yo IR2 on HIR m·min^{-1} and a positive effect of HIR m·min^{-1} on number of ball disposals independent of yo-yo IR2.



Independent Variable (X)	Mediator (M)	Dependent Variable (Y)	N	Bootstrap sample	Indirect Effect	R^2	P value
Yo-yo IR2	m·min^{-1}	Total Disposals	21	3000	0.01 ± 0.01	15.4%	0.44
Yo-yo IR2	m·min^{-1}	Champion Data Rank	21	3000	-0.02 ± 0.04	0%	0.58
Yo-yo IR2	m·min^{-1}	Coaches Rating	21	3000	-.003 ± 0.01	13.9%	0.7
Yo-yo IR2	HIR m·min^{-1}	Total Disposals	21	3000	0.02 ± 0.01	15.4%	0.06
Yo-yo IR2	HIR m·min^{-1}	Champion Data Rank	21	3000	0.018 ± 0.047	2.9%	0.7
Yo-yo IR2	HIR m·min^{-1}	Coaches Rating	21	3000	0.001 ± 0.008	25.1%	0.98

Figure 3.2: Mediation model showing the effects between variables. Units are presented as standardised regression coefficients and the standard errors are in parentheses. A summary of the indirect effect ± standard errors of the combinations through bootstrap technique is also shown. Asterix represents significance at the 0.1 level.

Adding playing position as a moderator to the above mediation model revealed that non-key position players strengthened the indirect effect by improving the relationship between yo-yo IR2 and HIR m·min^{-1} (indirect effect = 0.023 ±0.011, p =0.04), and HIR m·min^{-1} and number of ball disposals (indirect effect = 0.022 ±0.011, p =0.04). Furthermore, incorporating playing experience as a moderator strengthened the indirect relationship between yo-yo IR2 and ball disposals in the >50 match experience cohort (indirect effect = 0.024 ±0.012, p =0.04).

Discussion

This study aimed to identify a relationship between a physical capacity measure (yo-yo IR2) and Australian Football performance. The results showed that yo-yo IR2 is correlated with number of ball disposals and is mediated by HIR m·min^{-1}. These results present a succinct and novel model of the contribution of physical capacity to Australian Football performance. Noteworthy components of this model include: a) the total effect of yo-yo IR2 score to number of ball disposals; b) the effect yo-yo IR2 has on HIR m·min^{-1}; c) the effect of HIR m·min^{-1} on the number of ball disposals for a given yo-yo IR2 score; and d) the indirect effect of yo-yo IR2 and HIR m·min^{-1} on the number of ball disposals. Whilst relationships between physical capacities and performance have been observed in golf[25] and soccer[8], the present findings are the first to show an indirect effect of a physical capacity measure and Australian Football performance through a mediator (match exercise intensity). The magnitude of the indirect effect indicates that 15.4% of the variation in the number of ball disposals can be attributed to the indirect influence of yo-yo IR2 and HIR m·min^{-1}.

A notable finding from this study was that of all the combinations analysed, yo-yo IR2, HIR m·min^{-1} and number of ball disposals was the only combination to satisfy the mediation criteria. This shows that HIR m·min^{-1} is an important physical performance variable to increase when attempting to improve disposal count. Moreover, the present findings suggest that this can be achieved by improving yo-yo IR2 score. The relationship between yo-yo IR2 and HIR m·min^{-1} found in this study is similar to that seen in soccer research[3]. In contrast to the present findings, previous studies in professional soccer have shown that more successful teams have more ball involvements but do not travel as far at high intensity[26], suggesting a different relationship between HIR m·min^{-1} and number of passes than that observed in this study. The different findings between these studies highlight the distinct differences in technical and tactical demands of teams between soccer and Australian Football.

This study also investigated the mediation relationship using conditional variables (moderators) such as position played and player experience. The indirect effect on the number of ball disposals strengthened for non-key position players when added as conditions for yo-yo IR2→HIR m·min^{-1}. It is likely that tactical constraints of playing key position (i.e. full forward, fullback, centre-half forward and centre-half back) may limit the space a player works in, thereby, limiting the player to work within their physical capabilities. Similar justification has been suggested for the differences in playing positions in soccer[27]. The present study also showed that the indirect effect was strengthened in non-key position players compared to key position players for HIR m·min^{-1}→number of ball disposals. This finding may be partly explained by the relatively limited exposure to the ball typically observed in key position players. Indeed, Dawson et al.[28] reported that key position players had less contest

involvements compared to non-key position players. Therefore, limiting the space that a player can move in (i.e. imposed by either the players team strategy or opposition strategy) may reduce the importance of HIR $m \cdot min^{-1}$ for successful performance. Therefore, since key position players may not obtain the same performance benefits from having a high yo-yo IR2 score as non-key position players, they may benefit from focussing more training toward developing other physical capacities or technical abilities (i.e. muscular strength and power, repeated sprint ability, speed, defensive skills, goal kicking etc.).

Greater playing experience was also found to strengthen the relationship between HIR $m \cdot min^{-1}$ and number of ball disposals and moderate the indirect effect. This suggests that not only is the ability to perform HIR $m \cdot min^{-1}$ important to gaining ball disposals but experience may dictate whether a player has involvement with the ball. Whilst speculative, it is possible that more experienced players can read the play more effectively and place themselves in a more appropriate position to receive the ball and/or are more likely to beat an opponent in a one-on-one contest. Nonetheless, more research is still required to identify the specific characteristics experienced players possess that allows them to generate a greater number of ball disposals via the same HIR $m \cdot min^{-1}$ than their less experienced counterparts.

Conclusion

In summary, this is the first study to statistically model the effect yo-yo IR2 performance has on Australian Football performance. This is also the first study, to the author's knowledge, to use mediation analysis in sports performance research. The results demonstrated that yo-yo IR2 performance affects the number of ball disposals

gathered via HIR $m \cdot min^{-1}$, and is strengthened in non-key position players and those who have played greater than 50 matches. It should be noted, however, that this study was conducted at the beginning of the season and further research should aim at identifying if this model is adaptable to the middle and latter stages of a season. Further research expanding on this model should seek to identify other moderators or cofounding variables that influence these effects, explain the effects of interchange on HIR $m \cdot min^{-1}$, to identify if intervention to improve yo-yo IR2 or HIR $m \cdot min^{-1}$ will alter the number of ball disposals, and to identify the impact of number of ball disposals on the outcome of the match.

Practical Implications

- Non-key position players may improve their ball disposal count by improving their yo-yo IR2 score.
- Improvements in yo-yo IR2 score may improve match HIR $m \cdot min^{-1}$ in non-key position players at the beginning of the season.
- The mediation model provides a foundation to evaluate Australian Football performance.

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