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Relationship between Aerobic Fitness and League Positional Ranking of Clubs in a Professional Soccer League over Three Competitive Seasons

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This study examines the relationships between the clubs' level of aerobic fitness and their respective positional ranking as well as with the clubs' other league performance variables such as number of matches won, drawn or lost, goals scored or conceded, and total points accumulated at end of the league season, for three consecutive seasons. Outfield-position players from all clubs in the top division of the Singapore professional soccer league were tested for their aerobic fitness using the 20-m multi-stage shuttle run test (MST) at post pre-season training phase and the clubs' respective rankings and other performance variables at the end of the 2002, 2003, and 2004 league seasons were noted. There was a significant correlation between the clubs' mean MST results and their league positions for 2003 (Spearman's rho=-0.67, *P*=0.02), but not for 2002 and 2004 seasons (both rho=-0.37, *P*>0.22). Except for the variable of drawn matches in 2004, Pearson's correlation showed no other significant relationship between the clubs' MST and their other performance variables in all three seasons (*P*>0.05). Given the limited validity of the 2003 data, the present evidence suggests a poor association and lack of consistency in the relationships between clubs' aerobic fitness level and their league positional ranking and performance variables.

Keywords: maximal aerobic power, fitness, performance, Asian soccer

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1. Introduction

Although the majority of high-intensity bursts of activities during a soccer match are primarily anaerobic in nature, the importance of aerobic fitness cannot be underestimated (Glaister, 2005; Spencer, *et al.,* 2005). A positive causal relationship between soccer players' measured maximal aerobic power (or VO_{2max}) and their soccer-specific match performance has been demonstrated previously (Helgerud, *et al.,* 2001). The well-controlled study showed that twice a week of high-intensity aerobic interval running sessions performed over 8 weeks improved the players' aerobic fitness by 11% compared to a control group who performed only soccer-specific drills. During the study's post-intervention matches, players in the aerobic training group also increased their distance covered by 20%, doubled their high-intensity sprints, increased the number of involvements with the ball by 24%, and showed an overall greater work rate, as compared to the control group of players (Helgerud, *et al.,* 2001). The study's findings provided compelling evidence that the enhanced aerobic fitness through aerobic training improved the player's overall soccer performance during match-play.

There are additional benefits for players who possess high aerobic fitness. Players with relatively higher aerobic fitness recover faster following acute bouts of maximal effort than players with a lower level of aerobic fitness (Glaister, 2005; Tomlin & Wenger, 2002), and this is clearly important during the intense periods of match play which could be decisive to the game outcome. Aerobically fitter players tended to cover greater distances and perform more sprints during a game (Bangsbo & Linquist, 1992; Smaros, 1980). They also possess the enhanced capability to resist fatigue and are better able to sustain a high work rate throughout an entire match (Bangsbo, 1994; Ekblom, 1986). Players with high aerobic endurance levels have been reported to be able to better maintain their technical skills and mental concentration towards the latter part of the game than less fit players (Bangsbo, 1994). These views are consistent with studies showing that muscular fatigue could lead to poor performances in soccer skills execution such as shooting and passing (Kellis, *et al.,* 2006; McGregor, *et al.,* 1999) and that players with superior aerobic fitness tended to possess greater stores of muscle glycogen (Bangsbo & Mizuno, 1988). It is thus reasonable to suggest that the aerobically fitter team will be playing at a higher tempo and probably create more scoring opportunities than a less fit team. It was even postulated that if a team had a measured VO_{2max} of 6.0 $ml \cdot kg^{-1} \cdot min^{-1}$ more than the opposing team, the magnitude of this 'extra' aerobic capability would be equivalent to a work capacity of having an additional player on the field (Wisloff, *et al.,* 1998). Therefore the more aerobically fit the players in the team, the greater the team's chance of winning the match.

Aerobically fitter, compared to less fit players are also less likely to suffer acute (Gleeson, *et al.,* 1998; Rahnama, *et al.,* 2003) and chronic fatigue-related injuries (Chomiak, *et al.,* 2000; Eriksson, *et al.,* 1986; Hirano, *et al.,* 2003). Indeed, Hawkins, *et al.,* (2001) reported a higher risk for injuries being sustained in the latter stages of each half of a match, which was attributed in part to fatigue. Players with relatively higher aerobic fitness generally possess an overall better physiological base to cope with a higher training volume and they tended to recover faster post-match and/or post-training (Bangsbo, 1998). It was suggested that the enhanced aerobic-related capabilities in these players enabled them to perform at their optimum level throughout the entire playing season (Pinasco & Carson, 2005). Considering all the above arguments and assuming similarities in other aspects (i.e. technical skills and tactical competency), it could then be hypothesized that the club with the greatest level of aerobic fitness could potentially win a greater majority of matches and hence, theoretically, finish as the top team whilst the club with the lowest aerobic fitness level will finish at the bottom of the league positional standing at the end of the season.

Interestingly, there is published research supporting such a claim. Apor (1988) found that the top four teams in the Hungarian first division league were perfectly rank-correlated at the end of the season with the respective teams' mean measured VO_{2max} taken at the start of the season. A comparison analysis between two clubs in the Norwegian elite division showed that the top-ranked club had a higher mean measured VO_{2max} than another low-ranked club (Wisloff, *et al.,* 1998). Similarly in the Greek National league, the champion club had a significantly higher mean running velocity at lactate threshold point than both the middle-placed and the bottom-placed clubs (Kalapotharakos, *et al.,* 2006). These studies showed that clubs with more aerobically fit players tended to be placed higher in the league positional standing. Both of the former two studies have regularly been cited in soccer-related books and reviews as the definitive evidence for the importance of a high level of aerobic fitness in soccer success (e.g. Reilly & Williams, 2003; Hoff, 2005, Stølen, *et al.,* 2005; Arcelli & Ferretti, 1999).

Notwithstanding these studies, the claims that enhanced soccer success is due to the players' aerobic fitness per se may be too simplistic as many other factors are clearly involved in a club's overall performance in the league competition. The Apor study assessed only four clubs and did not provide the number nor the playing positions of the players tested in each club. The comparison analysis data from both the Norwegian and Greek leagues may not be entirely appropriate since the comparison was made between very performance-contrasting clubs, the champion vs. the middle and/or bottom club of the league. All these factors potentially reduce the validity of the studies' findings.

To appropriately assess the hypothesis that aerobic fitness is associated with league positional standing, there is a need to analyze and compare all the clubs

Table 1 Clubs' mean aerobic fitness level (i.e. number of completed shuttles) in the 20-m multi-stage shuttle run test (MST) and their overall performance and positional ranking for the 2002 S-League season. There were 12 clubs and each club played a total of 33 league matches.

Club	Number of players tested	MST	Number of matches Won	Drawn	Lost	Goals For	Goals Against	Goals Difference	Percentage of matches won	Total Points	Ranking
A	19	113±10	26	6	1	104	37	67	78.8	84	1st
B	16	117±10	18	10	5	71	42	29	54.5	64	2nd
C	12	112±17	17	8	8	80	39	41	51.5	59	3rd
D	16	110±12	16	11	6	67	39	28	48.5	59	4th
E	22	112±13	17	7	9	75	44	31	51.5	58	5th
F	22	111±13	15	5	13	59	67	-8	45.5	50	6th
G	22	101±14	13	6	14	47	48	-1	39.4	45	7th
H	20	115±12	11	6	16	62	84	-22	33.3	39	8th
I	23	104±15	11	4	18	49	72	-23	33.3	37	9th
J	11	102±9	7	4	22	45	84	-39	21.2	25	10th
K	24	103±10	6	5	22	50	103	-53	18.2	23	11th
L	12	115±13	2	6	25	33	83	-50	6.1	12	12th
Mean	18±5	110±6									

Note: Goals Difference = difference between Goals scored For and Against; Total Points = number of points accumulated from matches won and drawn; Percentage of Matches Won = number of matches won / number of matches played; Ranking = position of the club at the end of the league season.

in that division. The comparisons also need to be conducted over several seasons to determine that if such a relationship exists, it is consistently observable across the seasons. Thus the primary aim of the present study was to examine the relationship between the level of aerobic fitness of all the clubs in a top division and their league positional ranking over three consecutive league seasons. In addition, assuming that an aerobically superior club would be creating more scoring chances, it was postulated that the fitter clubs would be scoring more and/or conceding the least number of goals, and subsequently win a greater number of matches and hence accumulate more points at the end of the season. Therefore, a secondary aim of the study was to determine the relationship between the clubs' aerobic fitness and other performance variables in the league such as number of goals scored or conceded, winning game percentages, and total number of points accumulated.

2. Materials and Methods

2.1. Subjects

Registered players from all of the clubs participating in the S-League were invited to participate in this study. The data used for analysis was restricted to outfield-positions players as it was considered that although goalkeepers are valuable players, their aerobic fitness level was unlikely to influence the outcome of games. Due to scheduling difficulties and injuries, it was not possible to assess all players in each of the clubs for all the three seasons. The number of players tested in each club for each of the seasons are shown in **Tables 1-3**. The S-League administrators, clubs, and players provided informed consent prior to the study and the local institutional ethics committee approved the data collection procedures.

The S-League, established in 1996, is the top professional soccer division in Singapore. The league format comprises 10 to 12 clubs competing against each other over three rounds. The S-League season typically spans 10 months, from January to October. Players usually report back to their clubs

Table 2 Clubs' mean aerobic fitness (i.e. number of completed shuttles) in the 20-m multi-stage shuttle run test (MST) and their overall performance and positional ranking for the 2003 S-League season. There were 12 clubs and each club played a total of 33 league matches.

Club	Number of players tested	MST	Number of matches Won	Drawn	Lost	Goals For	Goals Against	Goals Difference	Percentage of matches won	Total points	Ranking
B	19	123±11	26	5	2	104	42	62	78.8	83	1st
C	14	124±11	21	5	7	75	30	45	63.6	68	2nd
A	9	119±8	20	7	6	68	37	31	60.6	67	3rd
D	14	109±13	17	5	11	63	40	18	51.5	56	4th
E	15	118±10	14	12	7	65	47	18	42.4	54	5th
G	11	118±10	12	8	13	35	34	1	36.4	44	6th
M	17	118±10	11	11	11	46	48	-2	33.3	44	7th
F	15	115±14	6	12	15	37	56	-19	18.2	30	8th
H	8	118±14	7	9	17	32	66	-34	21.2	30	9th
I	14	117±11	8	2	23	36	78	-42	24.2	26	10th
N	9	116±10	6	6	21	33	77	-44	18.2	24	11th
K	14	110±11	5	8	20	37	76	-39	15.2	23	12th
Mean	13±3	117±4									

Note: Please see **Table 1** for detailed explanation of the various terms. Two clubs (J and L, see **Table 1**) from the 2002 season withdrew and two new clubs (M and N) were admitted to the league in the 2003 season.

Table 3 Clubs' mean aerobic fitness (i.e. number of completed shuttles) in the 20-m multi-stage shuttle run test (MST) and their overall performance and positional ranking for the 2004 S-League season. There were 10 clubs and each club played a total of 27 league matches.

Club	Number of players tested	MST	Number of matches Won	Drawn	Lost	Goals For	Goals Against	Goals Difference	Percentage of matches won	Total points	Ranking
D	13	116±12	20	3	4	76	29	47	74.1	63	1st
B	15	120±15	17	2	8	76	43	33	63.0	53	2nd
N	14	109±10	14	5	8	74	52	22	51.9	47	3rd
A	14	117±16	14	3	10	45	48	-3	51.9	45	4th
O	16	132±4	12	8	7	50	42	8	44.4	44	5th
E	11	124±10	12	4	11	48	49	-1	44.4	37	7th
C	14	126±9	10	7	10	43	43	0	37.0	40	6th
K	14	114±10	6	2	19	36	73	-37	22.2	20	8th
M	13	120±7	4	5	18	36	62	-26	14.8	17	9th
I	14	120±10	4	5	18	29	72	-43	14.8	17	10th
Mean	14±1	120±7									

Note: Please see **Table 1** for detailed explanation of the various terms. Three clubs (F, G and H, see **Table 2**) from the 2003 season withdrew and a new club (O) was admitted to the league in the 2004 season.

during the first or second week of January after a protracted break of 8-10 weeks following the completion of the previous league season, to begin their pre-season training phase that lasts between 6-8 weeks. In this phase, the focus is on enhancing the players' aerobic fitness levels and overall conditioning, and the clubs generally train 7-10 times a week for 90-120 min per session and play several

friendly matches. The pre-season phase ends late February or early March and from hereon the league competitive season begins, lasting 8 months until late October. In this phase of competition, clubs train 4-6 times and play 1 or 2 competitive league matches per week.

2.2. Procedures

The study was conducted during the league seasons of 2002, 2003, and 2004. Each year the clubs' players were tested either the week prior to, or the week after the clubs' first official league match of the season. In a previous study, we tracked the clubs' aerobic fitness level throughout the entire league season and the majority of clubs had their highest mean aerobic fitness level following the completion of their pre-season training rather than in the middle or at the end of the season (Aziz, *et al.,* 2005). Thus it is reasonable to assume that the clubs' fitness level measured after the completion of their pre-season training was the clubs' mean highest aerobic fitness level for the season.

2.3. 20-m multi-stage shuttle run test (MST)

The MST was conducted outdoors on a synthetic running track either in the morning (0730 to 0930 hrs) or in the late afternoon (1730 to 1830 hrs) depending on the clubs' availability. Singapore is a tropical country and the local climate is consistently hot and humid all year round. The temperature and relative humidity for the morning and afternoon sessions ranged between 25-28 °C and 69-77% and 28-30 °C and 60-68%, respectively. A comparison between the pooled mean MST performance for the morning and afternoon testing sessions for the 2003 league season showed no significance difference (P>0.05) (Aziz, *et al.,* unpublished observation).

The MST's procedures were identical to those previously described by Ramsbottom, *et al.* (1988). Briefly, groups of four to eight players ran back and forth between two lines, spaced 20-m apart, in time with the "beep" sounds from a compact disc (*20-m Shuttle Run test CD, Australian Sports Commission, Canberra, Australia*). Each successful run of the 20-m distance constituted the completion of a shuttle. The "beep" would sound at a progressively increasing pace with every minute of the test and the players were required to concurrently increase their running speed. The players wore non-cleat shoes and were allowed to perform their own warm-up. Verbal warnings were given if the players did not reach the end line on time and the test was terminated when the player: i) could not follow the set pace of the "beeps", that is, make it to the end of the 20-m lines within the given time on two successive shuttles, and/or ii) stopped voluntarily. The MST is typically scored in levels and shuttles, but these values are discontinuous and cannot be used in statistical analysis. In the present study, the number of successfully completed shuttles in the MST was reported as the player's aerobic fitness level and used in the statistical analyses. In addition, the number of completed shuttles was also converted to estimated VO_{2max} based on the norms table of Ramsbottom, *et al.,* (1988) to provide a basis for aerobic fitness level comparison with previous studies.

2.4. Clubs' positional ranking at the end of the league season

The end of season positional ranking of the clubs and other related information such as number of matches played, number of goals scored for and against, goal difference, number of matches won, lost and drawn, total accumulated points, and percentage of won matches were all directly obtained or calculated from the league tables available from the S-League's official website (http://www.sleague.com/ina0802.asp; retrieved 1st December 2005).

Typically, clubs were given 3, 1, and zero points for a win, draw, and loss respectively. However in the 2003 season, the S-League administrators introduced a 'modified' system where for matches ending with a draw after the full 90 min of play, each team was awarded 5 penalty kicks to decide the winner. The winner of the penalty kicks would then receive an additional point (i.e. total of 2 points; one for the 90 min drawn match and another point for winning the post-match penalty kicks), whilst the other team would receive only a single point for the drawn match. The additional points obtained from the penalty kicks system was not part of the full 90 min of normal play, and hence the clubs' gains from it was not directly related to players' aerobic fitness per se (Jordet, *et al.,* 2007). Thus for the purpose of the present study, the 'additional points' awarded to the clubs from their success in the penalty kicks system throughout the 2003 season was calculated

Table 4 Correlation coefficient (Spearman's) between the clubs' mean aerobic fitness performance (i.e. number of completed shuttles) in the 20-m multi-stage shuttle run test (MST) and the respective clubs' positional ranking at the end of league season 2002, 2003, and 2004.

	Clubs' Positional Ranking for league season		
	2002	2003	2004
Clubs' aerobic fitness performance	-0.37	-0.67*	-0.37
P value	*0.23*	*0.02*	*0.24*

and deliberately deleted from the clubs' total points accumulated at the end of the 2003 season. Appropriate adjustments were then made to the clubs' points accumulated and thus to their final positional rankings, which is reflected in the present study's **Table 2**.

2.5. Statistical analysis

All descriptive data are presented as mean ± standard deviation of the mean. The Statistical Package for Social Sciences, SPSS 11.5 for Windows (SPSS Inc., Chicago, IL) was used for all statistical analyses. Comparison analyses between selected variables were calculated within each of the league seasons independently. Bivariate analysis using the Spearman's rank correlation (*rho*) was conducted to determine the correlation between the clubs' MST results and their positional league rankings. Pearson's product correlation (*r*) was used to determine the relationship between the clubs' MST results and their other league performance variables (e.g., total points accumulated, number of matches won, drawn or lost, match winning percentage, goals scored for and against). The significance was set at $\alpha = 0.05$.

3. Results

Tables 1-3 show the clubs' mean MST results and their overall performance in the league for the 2002, 2003, and 2004 seasons, respectively. There were 12, 12, and 10 clubs involved and each club played 33, 33, and 27 league matches in each of the league seasons, respectively. The average number of outfield-positions players tested per club was 18.3 ± 4.7 in 2002, which was significantly higher than 13.3 ± 3.4 and 13.8 ± 1.3 players in 2003 and 2004, respectively ($P<0.01$). The clubs' mean MST results in 2002, 2003 and 2004 are equivalent to estimated VO_{2max} scores of 54.8, 56.8 and 57.6 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively (range across all three seasons were 52.2 – 60.8 $ml \cdot kg^{-1} \cdot min^{-1}$). These data indicate that the S-League players' level of aerobic fitness generally falls within the range of mean values reported for professional soccer players (Kalapotharakos, *et al.,* 2006; Reilly, 2005; Roi, *et al.,* 1993; Tiryaki, *et al.,* 1997), but are considerably lower in comparison to top-league professionals (Casajús, 2001) and world-class players (Reilly, *et al.*, 2000; Stølen, *et al.,* 2005).

Table 4 shows the correlation between the clubs' aerobic fitness level and their position in the league for the three seasons. There was no significant correlation between the clubs' mean MST result and their positional ranking for the 2002 and 2004 league seasons. There was, however a significant moderate correlation between the clubs' MST results and their positional ranking for the 2003 season. **Table 5** shows the clubs' aerobic fitness with their other league performance variables. Pearson correlation analyses showed a significant relationship between aerobic fitness and drawn matches in the 2004 season, but this relationship has limited practical implication and is not a key performance indicator of success in soccer. In all three seasons, there were no other significant correlations between the clubs' MST and their league performance variables (all $P>0.05$).

4. Discussion

The purpose of the present study was to examine the relationship between the clubs' aerobic fitness and positional ranking and performance in the

Table 5 Correlation coefficient (Pearson's) between the clubs' mean aerobic fitness performance (i.e. number of completed shuttles) in the 20-m multi-stage shuttle run test (MST) and the respective clubs' other league performance variables at the end of the league seasons 2002, 2003, and 2004.

	Clubs' MST result		
	2002	2003	2004
Clubs' other Performance Variables			
Number of matches won	0.35	0.56	-0.12
Percentage of matches won	0.35	0.53	0.56
Number of matches drawn	-0.44	-0.10	0.64*
Number of matches lost	0.37	0.56	-0.12
Number of goals scored for	0.45	0.50	-0.31
Number of goals scored against	-0.34	-0.43	-0.26
Goal difference	0.42	0.52	-0.06
Total accumulated points	0.39	0.56	-0.04

*$P = 0.047$

league competition. In comparison to previous research, the novelty of the present study is due to the inclusion of all clubs in the division, analysis of other performance variables in the league (e.g., goals scored and conceded, number of wins, etc), and the tracking of statistical relationships over three consecutive league seasons.

A significant relationship was found between the clubs' aerobic fitness level and their positional ranking in 2003, but not in the 2002 and 2004 seasons. With the exception of a significant correlation between aerobic fitness and drawn matches in 2004, there was no other association between the clubs' aerobic fitness levels and any of the other league performance variables such as the number of matches won (and winning percentage) or lost, or the number of goals scored for, and goals scored against and total points accumulated, in all the three seasons **(Table 5)**. Thus the major finding of the present study is that there is a lack of association and consistency in the relationships between the clubs' mean aerobic fitness and their positional ranking and other performance variables in the league.

Although there was a relationship between the clubs' aerobic fitness and positional rankings in the 2003 league season, we interpret this association with caution. That year, the S-League management introduced the system of penalty kicks to decide the winner for drawn matches (see detailed explanation in the Methods section), which caused some unorthodox tactics to which some clubs approached their league matches. During the team managers' meeting at the end of 2003 to review the end-of-drawn game penalty kicks system, it was revealed that a much weaker club would deliberately adopt a very defensive strategy against an established stronger club in their match in order to draw the 90 min match and then hopefully gain another advantage point during the penalty kicks. This view is supported by the fact that there were more drawn matches in 2003 compared to 2002, with each club averaging 7.5 vs. 6.5 drawn matches respectively, even though the clubs played the same number of matches in both seasons. Because of this defensive tactic adopted by some of the clubs, the penalty kicks system was immediately removed for the 2004 season. Secondly, there were no statistically significant relationships between aerobic fitness and other key performance variables assessed in 2003, or

in the other two seasons. Thirdly, the mean number of players tested per club in 2003 was the lowest among the three seasons with three of the clubs having less than nine players tested. It is plausible that the low number of players tested in the three clubs may have artificially inflated the three clubs' mean MST result. Considering all these factors, it was reasoned that the overall 2003 data possesses limited validity and that the statistically significant relationship between clubs' aerobic fitness and their league rankings in 2003 was more likely due to chance.

The present study data do not concur with the observations of Apor (1988), Wisloff, *et al.* (1998), and Kalapotharakos, *et al.,* (2006), but are supported by others. For example, Roi, *et al.* (1993) tracked a single professional club in the Italian first division league for six consecutive seasons. Players' measured aerobic fitness (i.e. VO_{2max}) was performed using gas analysis during the pre-season phase from the 1984-1985 to 1989-1990 league season and the club's league ranking at the end of each season was noted. Whilst there was no statistically significant difference in the players' measured VO_{2max} in the six seasons (ranged 51.2 to 56.9 $ml \cdot kg^{-1} \cdot min^{-1}$, $P>0.05$), the club's position in the league ranged from a high of 8th (1985-1986 season) to a low 15th (1986-1987 season) with the club being relegated to the second division in the 1987-1988 season. This study showed that whilst the measured VO_{2max} of the club as a whole did not change significantly, the club's position varied substantially from season to season. The authors concluded that there was a poor relationship between VO_{2max} and soccer performance and that club's ranking was affected by factors other than aerobic fitness alone (Roi, *et al.,* 1993). In the Kalapotharakos, *et al.,* (2006) paper, there was a significance difference between the top- and middle-placed club, but yet there was no significant difference in mean running velocity at lactate threshold point between the middle-placed and the bottom-placed club ($P>0.05$) in the Greek league. In another study, it was observed that the mean aerobic endurance performance via the Cooper' run test was not significantly different between three professional teams taken from the first, second, and third divisions ($P>0.05$) of the Turkish soccer league (Tiryaki, *et al.,* 1997). Similarly, there was no significant difference in aerobic fitness as estimated from running performance on a treadmill, between the top two clubs ($P>0.05$) in the Macedonian first league (Metin & Handziski, 2003). These studies indicate that aerobic fitness levels do not seem to correlate well with positional rankings. We speculate that the contrasting findings between the studies is probably due to the differences in the studies' experimental design, number of clubs or teams assessed, type of aerobic fitness tests used, and differing standard of competition, or even styles of play between the leagues from different countries. For example, it is common knowledge that the game of the English Premier league division is characterized by a direct approach to goal scoring, which is fast and physically demanding whilst the game in the Italian Serie A is characterized by a more tactical and technical methodical approach to goal (Reilly & Williams, 2003). This implies that the former league generally requires all players to maintain a high work rate throughout a match and is hence more aerobically demanding than the latter league matches. Indeed, a recent study showed significant differences in age, body mass, body mass index, and quality of players (as determined by the players' FIFA world rankings of countries) among the players in the English Premier, Spanish La Liga, Italian Serie A, and German Bundesliga leagues (Bloomfield, *et al.,* 2005). The authors argued that one of the reasons for the observed differences was the different physical demands and/or style of plays of the four leagues (Bloomfield, *et al.,* 2005).

Nevertheless our findings do not dismiss the importance or benefits of aerobic fitness in soccer players which has been established previously (Helgerud, *et al.,* 2001), but rather suggest that global soccer success in the leagues is multifactorial and that aerobic fitness is not the sole determining factor in winning matches (e.g. Low, *et al.,* 2002). In fact it can further be argued for the relative greater importance of aerobic fitness in the Singapore soccer scene as compared to that of the European leagues. This is due to soccer matches in Singapore typically being played in very hot and humid conditions (with average temperature and relative humidity during matches throughout the season ranging between ~28-32 °C and ~65-80%; our unpublished observations) and research data has shown that elevated environmental conditions can lead to a more pronounced or early onset of fatigue in players during matches (Ekblom, 1986). Given the moderate level of aerobic fitness in the average

player in the present study, it is pertinent to highlight to the clubs' coaches a need to further improve the level of this fitness capacity in the S-League. Clubs who routinely assessed the physiological attributes of players have always included a test of aerobic fitness and this practice is a strong testament to the perceived importance of aerobic fitness per se by the coaching staff. Indeed, renowned soccer sport-scientist Professor Reilly has previously suggested a minimum threshold level for measured VO_{2max} of 60 $ml \cdot kg^{-1} \cdot min^{-1}$ for top professional soccer players (Reilly, *et al.*, 2000). Given that the present game has been shown to be played at a much greater pace as compared to the previous decade (Humboldt, 2003; Williams, *et al.,* 1999), it is not surprising that an even higher value of 70 $ml \cdot kg^{-1} \cdot min^{-1}$ was recently recommended to perform optimally at the very top-level (Stølen, *et al.,* 2005). All these indicate that a high level of aerobic fitness is well recognized as an important fitness attribute in all outfield-position players.

Given the field study nature of the present research design, some inherent limitations are unavoidable. Firstly, we were not able to assess all the outfield-position players in each of the clubs for all three seasons because of the clubs' tight training and match schedule and injury to players. Secondly, the actual playing time during matches for those players whose fitness was assessed at the start of the season was not obtained. Further investigation in this area should focus on addressing these limitations. Future studies should also endeavor to assess the contribution of the fitter players towards winning matches by tracking their playing time, distance covered during high-intensity movements, and overall work-rate via time-motion video or global positioning systems (Edgecomb & Norton, 2006).

5. Conclusion

The present study showed a poor association and lack of consistency in the relationships between the clubs' level of aerobic fitness and their positional league ranking, as well as with the clubs' other league performance variables across three league seasons. Global success in the league involves more factors than simply the clubs' level of aerobic fitness per se.

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