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Relation between lower limb comfort and performance in elite footballers

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ABSTRACT

Objectives: Successes of the professional athlete as individuals and team, across codes of football are contingent upon performance measures. The aim of the study was to examine associations between comfort and performance.
Design: Prospective measures of lower limb comfort and coach rating performance criterion. Comfort and performance associations were described using Pearson's correlation coefficient (r) or the R square value from the regression estimate.
Setting: Two professional football codes in Australia.
Participants: 79 professional footballers were followed for one football season, a total of 1724 player weeks.
Main Outcome Measures: Study hypothesis was poor lower limb comfort is negatively correlated with good match day rated performance. Aspects of validity and responsiveness to change tested the hypothesis that lower limb comfort, affects rated performance. A validated lower limb comfort index (LLCI) was used to test comfort. Rated performance was evaluated by subjective rating criterion of experienced team coaches.
Results: Poor lower limb comfort and good match day ratings were not well correlated ($R^2 = 0.25$, $P \leq 0.001$) and usual-high comfort was correlated with usual-good performance ($R^2 = 0.69$, $P \leq 0.001$).
Conclusions: Lower limb comfort may be a sensitive measure of rated performance in football. The LLCI is the first measurement tool to show association between comfort and rated performance.

1. Introduction

Performance is an area of elite sport in which all athletes and coaches strive to improve. Because there is no one accepted measure of sporting performance (Young & Pryo, 2007), various measures of performance are used to assess individuals. These range from quantitative game statistics using parameters such as running distance covered, speed intensity, speed high intensity distances, (Coutts & Duffield, 2010) to assessment of game skills (Szczepański, 2008) as well as physiological and anthropometric testing (Reilly, Bangsbo, & Franks, 2000).

There are also psychological, technical and tactical factors, the measures of which are largely subjective as one person's opinion of skill execution will differ from another. Despite acknowledged limitations, subjective judgements of performance are sufficiently credible and trainable to be accepted as valid scoring systems in Olympic and World Championship events such as diving, gymnastics and boxing. In regard to football performance, opinions canvassed among AFL coaches in a state league competition, showed team performance was associated with various skill executions (Twomey, Finch, Roediger, & Lloyd, 2009) and as such, also showed subjective opinion has an element of credibility.

Injury has socioeconomic and financial consequences (Dvorak et al., 2000) and also affects sporting performance. Pragmatically a link between injury and performance is clear. However, there is limited corroborative evidence to support this link. A speculative theory is performance, like injury, has a multi-factorial aetiology including factors such as varying states of psychological and physical well being, environmental and equipment factors. The role of neurophysiology and neuromuscular responses and pain inhibition as a determinant of performance is not well understood. However, comfort may play a role in determining performance (Luo, Stergiou, Worobets, Nigg, & Stefanyshyn, 2009) among the football codes (Hagglund, 2007; Orchard & Seward, 2009).

The lower extremities have been identified as a dominant region of the human body vulnerable to injury in the football codes (Hagglund, 2007; Orchard & Seward, 2009), running (van

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Middelkoop, Kolkman, van Ochten, Bierma – Zeinstra, Koes, 2008) and multiple other sports (Twomey et al., 2009). Therefore an extension of the injury paradigm in sport is an investigation of whether lower limb comfort affects performance. Previous studies of footwear discomfort, propose an alteration of lower extremity muscle loading during running may cause muscular fatigue and be detrimental to subsequent performance (Nurse, Hulliger, Wakeling, Nigg, & Stefanyshyn, 2005; Wakeling, Pascal, & Nigg, 2002). The mechanism by which this occurs involves the capacity of the body's sensory system to respond to variations of footwear stimuli or lower limb discomfort which alters impact forces (Miller & Hamill, 2009; Zadpoor & Nikooyan, 2010). Strong evidence supports the theory of comfortable footwear providing a protective function to the lower extremity by load attenuation and cushioning that collectively creates a state of comfort (Mündermann, Stefanyshyn, & Nigg, 2001; Nigg, Nurse, & Stefanyshyn, 1999; Witana, Goonetilleke, Xiong, & Au, 2009; Yung-Hui & Wei-Hsien, 2005). Performance can also be affected by muscle soreness (Reilly, Drust, & Clarke, 2008). Mechanical damage to muscle leads to discomfort and affects athletic performance altering strength, range of motion, proprioception and gait biomechanics (Byrne, Twist, & Eston, 2004). Altered muscle sequencing results in disruption to usual movement patterns and compensatory musculoskeletal mechanisms may occur, compromising performance and increasing the risk of injury (Cheung, Hume, & Maxwell, 2003).

Techniques used to assess the health of athletes which may effect performance of athletes include systems to track wellness (von Guenthner & Hammermeister, 2007), monitoring of physical loads (Hartwig, Naughton, & Searl, 2008) regular assessment of players physical profiles (Rösch, Hodgson, Peterson, Graf – Baumann, Junge, Chomiak, Dvorak, 2000) and health related screening programs (Holzer & Brukner, 2004).

Pertinent to the lower limb, the role of neuromuscular and neurophysiologic effects of increased loads, musculoskeletal disorders, delayed onset muscle soreness, and factors that detrimentally impair player wellness, may affect the ability to train and so compromise football conditioning (Gabbett, 2006) and also impair performance skills (Verrall, Kalairajah, Slavotinek, & Spriggins, 2006). A lower limb comfort index previously used in elite football was shown to be reliable and valid (Kinchington, Ball, & Naughton, 2010). The theoretical basis for this proposition is the complex interaction between the cerebral cortex and neural stimuli which differentiates between a state of discomfort (pain) and comfort (Karoly & Jensen, 1987). The response of the musculoskeletal system to loading involves the capacity of the body' to respond to variations of impact forces associated with activity (Mündermann, Nigg, Humble, & Stefanyshyn, 2003; Zadpoor & Nikooyan, 2010). When tolerance levels are breached, pain and discomfort results which alters the rate at which lower extremity muscle loading occurs and has been linked to musculoskeletal disorders, muscular fatigue and performance effects (Wakeling et al., 2002).

By measuring limb comfort over time, quantitative data on the physical preparedness of a player can be obtained. An extension to the potential use of comfort to determine injury (Kinchington et al., 2010), is the proposition that comfort, which is measured by a lower limb comfort index (LLCI), may also affect performance.

In the environs of elite sport, athletes are rarely free from musculoskeletal discomfort and often will contend with multiple areas of discomfort at the one time. Thus some capacity of athletes to perform well with discomfort and injury may be a necessary condition for elite sports participation.

A system that evaluates comfort may provide a mechanism to measure the overall state of lower limb well being, and be compared to performance measures. The aim of this study was to examine the association between lower limb comfort and rated performance, the foci being the evaluation of rated performance of professional footballers using subjective rating criterion of experienced team coaches on individual player's game response.

2. Methods and materials

2.1. Data collection

The cohort for this study comprised 79 athletes from two football codes played in Australia (Rugby Union, and Australian Rules). Aspects of validity and responsiveness to change were used to test the hypothesis that lower limb comfort affects performance. Lower limb comfort data were collected using a previously validated index (Kinchington et al., 2010). The data were collected following a final training session for each week of in-season competition which represented 24–30 h before match participation (match day). Letters of support for the study were obtained from the respective organizations. Ethics approval was granted from the Human Ethics Committee at Victoria University, Australia.

2.1.1. Lower limb comfort

Lower limb comfort was prospectively collected for the period of the study using a previously described protocol (Kinchington et al., 2010). For home venue games, the data were collected in an environment familiar with the players. For away venues, the data were collected at the hotel at which the team was residing. The researchers supervised the entry of data by the players at all home ground matches, and when data collection occurred at away matches, the medical and conditioning staff of the respective football organizations assisted with data collection. Throughout the study, the lower limb comfort data remained confidential and were not provided to the coaching staff and were not used as selection criteria. The players were aware the comfort data they provided would not negatively prejudice match participation.

A sum score for lower limb comfort was calculated for each player and represented an aggregation of six anatomical areas (foot, ankle, calf-achilles, shin, knee, football boot) totalling 36 points. Each anatomical area was scored between 0–6. A score of 0 indicated extreme discomfort, being unable to run or jump, and 6 was extremely comfortable. Comfort zones for each player were determined post-hoc using median scores from the collected data. Post-hoc was defined as end of season (16 rounds of competition in the Rugby Union Super 14, and 26 collected events in the Australian Rules national competition). The analysis of post-hoc comfort data was deliberate to allow for significant changes to comfort levels which may have occurred during the monitoring period, because lower limb zone comfort may re-set due to football relevant factors including surgery, football conditioning, and changing musculoskeletal maturity.

Three comfort zones were established. Each zone was apportioned an arbitrary colour to reflect level of comfort using a previously validated method to monitor lower limb comfort (Kinchington et al., 2010). The calculations used for the three comfort zones were: Poor (red zone) comfort $^{\text{median } -2 \text{ comfort points}}$; Usual (black zone) comfort $^{\text{median } \pm 1 \text{ comfort}}$; High (blue zone) comfort $^{\text{median } +2 \text{ comfort points}}$. The apportioning of the upper and lower zones was established by trials using other scores above and below the median. The use of ±1 above or below the median was too narrow to delineate high and poor zone because it did not allow for some fluctuation in factors. Scores ±3 created a range too wide to establish meaningful outcomes. Comfort and performance which are not empirical measures by their nature will vary. Therefore, a median range is appropriate.

2.1.2. Rated performance data collection

Lower limb comfort was compared to rated match day performance to assess the extent to which lower limb comfort was related to performance. For the purpose of this paper, performance was defined as the collective subjective rating of experienced coaches on each player's game response. The measurement of performance for each code of football was limited to subjective evaluation by four members of the coaching staff for the respective code of football. The ratings of performance were inclusive of physical and tactical responses of the players. While notional data using parameters such as workloads, running distances, ball possessions, tackles and number of kicks are relevant criteria to quantify performance, non-quantifiable parameters such as the influence of ground environment, game tactics, and importantly specific coaching instructions to a player are considered integral to individual rated performance. It is these subjective, non-quantifiable areas of performance; i.e. coach evaluation of known tasks for each player based on game plans were the broad criteria used by the coaching staff to rate the performance of players.

The exact criteria may differ between clubs and guidelines which suit one club may not be considered important to another club or code of football. Therefore knowledge of the criteria used to rate player performance is not relevant to the study. The researchers were blinded to the methods used to evaluate performance and did not access the data until the end of the collection period. Performance zones were determined post-hoc using median scores from the collected data. Using the same format to rank lower limb comfort, match day rated performance were classified into zones: good (blue performance rating), usual (black performance rating), and poor (red performance rating).

2.2. Statistical methods

Data were analysed using SPSS v 15.0 for Windows (2006). For all analyses, P values less than 0.05 were considered statistically significant. Continuously distributed variables were summarized as means, standard deviations (SD) and 95% confidence intervals (95% CI) where appropriate. To display results graphically, box plots and column graphs were used to show comfort zones and match day ratings. In the box plots, the dark line represents the median value, the box represents the 25–75% percentiles and the whiskers show the range. Scatter plots were used to display associations between two continuous variables. The size of the association between continuous variables was described using Pearson's correlation coefficient (r) or the R square value from the regression estimate.

3. Results

Descriptive data for participants were age: mean 24.1 years (SD 3.6), weight 95.2 kg (SD 8.3); height 184.4 cm (SD 5.1) cm. No significant differences were observed in age and anthropometric measurements between the two different codes of football recruited for the present study. A total of 1724 player weeks of data were collected, mean 21.9 (SD 11.5) weeks per player. Of the cohort recruited, data for 79 players was utilized. Data for 13 players was excluded due to insufficient numbers of comfort events recorded, not enough match rating exposure events and player data which were more than 3 SD from the group outliers were excluded because they would bias results in favour of the research hypothesis.

3.1. Match day comfort

Match day ratings were compared to match day comfort events at the end of the data collection period. Fig. 1 shows match day comfort for 79 participants for 1724 data collection events. Poor comfort (red zone) represented 25% of lower limb comfort scores, and Usual and High comfort (black and blue zones) represented 75% of comfort events. Usual and high comforts were combined, as the two comfort zones were not considered to be detrimental to performance. The median number of usual and high comfort events as represented by black-blue zones was 13 per player. This was an expected result as comfort changes with time and for many weeks players will participate with some level of discomfort. The median number of red comfort events was five (5) per player.

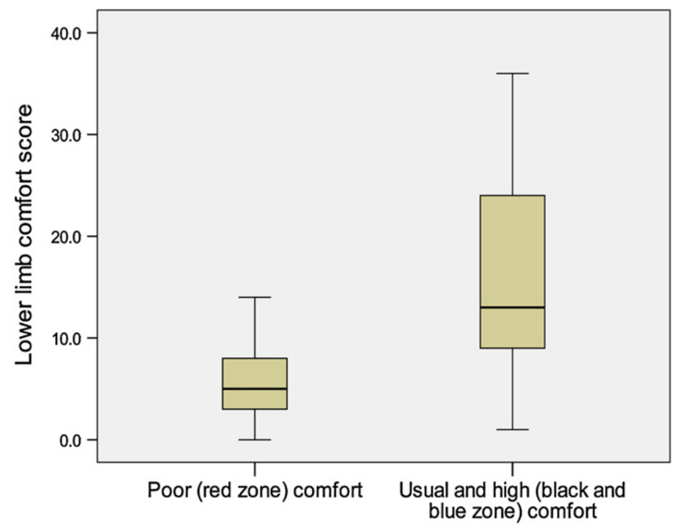

Fig. 1. Comfort events for 79 players from two codes of professional football (Australian Rules and Rugby Union).

3.2. Relation between comfort and performance

Fig. 2a compared match ratings with poor (red) comfort scores. When poor comfort scores were recorded (426 events) there was a high proportion of poor match ratings (60.3%) and a low number of high (blue) match ratings (5%). The results show a clinical trend between poor (red) zone comfort scores and poor (red) match performance ratings. The conclusion was when players' lower limb comfort is poor; performance was compromised when using coach ratings as a measure of performance. However, a direct association between the comfort and match rating scores did not occur on all occasions, as usual (black) match ratings (35%) and high (blue) match ratings (5%) still occurred with poor comfort scores. Nevertheless, the result for good performance indicates it was unlikely an individual performance would be rated good or usual when lower limb comfort was poor.

Fig. 2b shows how usual (black) and high (blue) lower limb comfort scores were matched to performance ratings. When comfort scores were not considered poor, there was a strong association to usual-good match ratings (77%) and a weak relationship to poor match ratings (23%).

These results reinforce the outcomes shown in Fig. 2a where poor (red) comfort was likely to effect match ratings. When LLCI scores were ranked as usual and high (black-blue) comfort 23% of occasions showed a poor match rating. The inference drawn from these results is while usual high comfort has benefits for performance; factors that affect performance are not only related to lower limb comfort. The overall results support the research hypothesis that red zone scores (poor lower limb comfort) are not well correlated to high rating match performances.

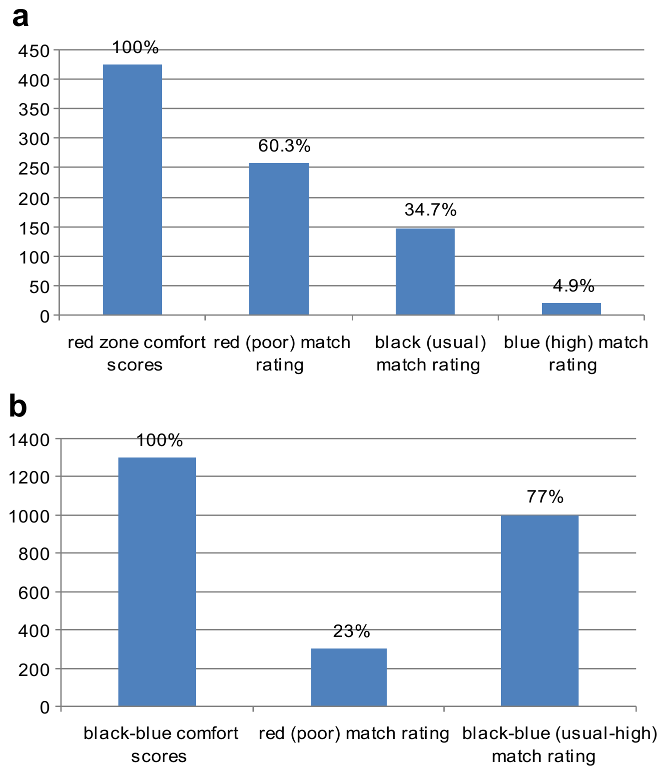

Fig. 2. (a) The proportion of performance (match ratings) to poor comfort (red zone) events (*y* axis), (b) The proportion of performance (match ratings) to usual (black) and high (blue) comfort events (*y* axis).

The scatter plots show the spread of zone match ratings (poor [red], regular [black], high [blue] relative to poor lower limb comfort. Fig. 3a shows poor comfort was correlated with poor match ratings ($R^2 = 0.62$, $P \leq 0.001$) indicating a strong association between poor lower limb comfort and a poor match rating. In one example, the plot shows a direct relationship between poor (red) comfort (8 events) and poor (red) match ratings (8 events). Conversely, relatively few poor comfort ratings were associated with zero poor match ratings showing the probability of a poor match rating when registering poor lower limb comfort. However, poor comfort was not well correlated with regular (black) match ratings ($R^2 = 0.42$) and was poorly correlated with good (blue) match ratings ($R^2 = 0.25$) indicating that poor lower limb comfort is not associated with high match ratings.

As comfort improved, there were an increasing number of zero match rating events, an indication that poor comfort was not associated with better match ratings (Fig. 3b and c). Fig. 3c shows a broad scatter of match ratings indicating a weak relationship between high match ratings and poor comfort events. The range of high match ratings was 0–3 for each player, but with a large number of poor comfort events (16 events). The highest high match rating was 3 events which occurred with 13–14 poor comfort events and was indicative of the weak relationship between poor lower limb comfort and high performance when measured by coach value ratings.

The graphical results are confirmed by statistical evidence. Table 1 shows the relation between the number of comfort events and the match day ratings. The correlations were highly statistically significant for poor (red) comfort events, less significant for usual (black) comfort events and highly significant for usual and high comfort when combined (black-blue comfort) showing, for all classifications, that increased comfort events were associated with higher match ratings.

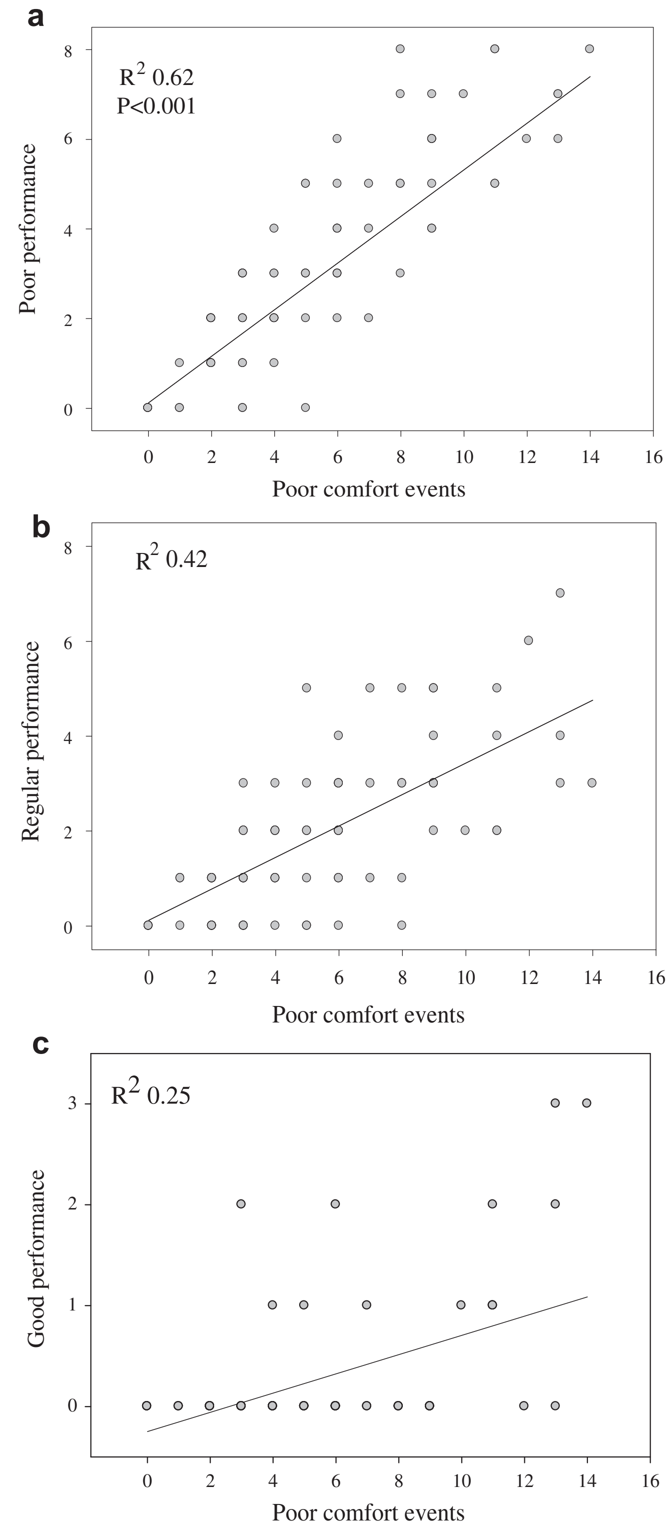

Fig. 3. (a) Relation between poor lower limb comfort and poor performance ratings, (b) Relation between poor lower limb comfort and usual (median range) performance ratings, (c) Relation between poor lower limb comfort and good performance ratings.

3.3. Case studies of comfort and performance

Tables 2a and 2b represent case examples of comfort and rated performance data for two squad players from separate football codes who were representative of their respective groups. Scores

Table 1
Relation between comfort and performance measured as a match day rating.

	Poor (red) match rating	Usual (black) match rating	Good (blue) match rating	Usual and good (black-blue) rating
Poor (red) comfort scores				
Linear regression R^2	0.62	0.42	0.25	
Pearson correlation	0.79	0.66	0.50	
P value	<0.0001	<0.0001	<0.0001	
N	79	79	79	
High (blue) comfort scores				
Linear regression R^2	0.08	0.07	0.004	
Pearson correlation	0.28	0.27	0.20	
P value	0.013	0.018	0.08	
N	79	79	79	
Usual and high (black-blue) comfort scores				
Linear regression R^2	0.48			0.94
Pearson correlation	0.69			0.97
P value	<0.0001			<0.0001
N	79			79

were given for comfort and rated performance and represent match participation. Where no scores are entered the players were injured and did not participate in the match. There were no differences between the football codes in relation to outcome data, showing the versatility of the LLCI between different codes of football. However, Table 2 which represents a footballer in the Super 14 Rugby Competition shows a higher proportion of missed games due a contact injury which is consistent with the rugby codes having more contact injuries than Australian Rules.

Table 2a shows lower limb comfort and match ratings of a player for each given week over one complete football season. The median lower limb comfort was 29, and median match rating 14 enabling zones to be allocated around the respective median scores. In this example, there was a direct relationship between poor (red) comfort ratings and poor match ratings on five occasions over the period of data collection. The only week in which there was no direct relationship was round 4. There was also a direct relationship for high (blue zone) comfort and good performance (blue match rating). This was recorded on 4 occasions. For the remaining weeks, usual comfort (black) was registered with generally a regular (black) match rating scored. However, due to variances in performance by a player there will not always be a direct relationship between comfort and ratings. For weeks 6 and 23 black (usual) comfort ratings were associated with a red (poor) performance and in week 7, a blue (good) rating was scored.

Table 2b depicts an elite rugby player whose season was affected by injury. The player sustained six missed games due to a leg injury of a contact nature which never fully recovered during the season. The LLCI registered high comfort and subsequent good rating performances were allocated by the coaching staff to the player early in the season (Rounds 1–2). However, a leg injury of a contact nature sustained during training, resulted in six missed matches over the next 14 rounds of football. The table shows that during the mid portion of the season the player returned from injury (round 4) and registered comfort in the usual range for the individual and scored a good performance rating. However, the player succumbed to the same injury in Round 6, and Rounds 8–10. On return from injury (Round 11), the player regained his regular 1st Grade spot, but rated performances were poor during Rounds 11 and 12. The consequence of poor performances and poor lower limb comfort was the inability to compete at the higher intensity levels associated with 1st Grade football. This case study was considered by the authors to be representative of others within the cohort that

Table 2a
Comfort and rated performance for a Australian Rules player for 26 weeks of football participating in the Australian Football League.

Player	Opposition	Team	Lower limb comfort score	Match rating score	Association between comfort and match ratings
Name Round 1	xxx	2nd grade	**33**	**19**	High–Good
Name Round 2	xxx	1st grade	**30**	**13**	Usual–Usual
Name Round 3	xxx	1st grade	**30**	**15**	Usual–Usual
Name Round 4	xxx	1st grade	**26**	**14**	Poor–Usual
Name Round 5	xxx	1st grade	**31**	**19**	High–Good
Name Round 6	xxx	1st grade	**30**	**12**	Usual–Poor
Name Round 7	xxx	1st grade	**28**	**17**	Usual–Good
Name Round 8	xxx	1st grade	**27**	**8**	Poor–Poor
Name Round 9	xxx	1st grade	**29**	**14**	Usual–Usual
Name Round 10	xxx	1st grade	**25**	**12**	Poor–Poor
Name Round 11	xxx	1st grade	**29**	**13**	Usual–Usual
Name Round 12	xxx	Injured	**xx**	**xx**	No association due to injury
Name Round 13	xxx	Injured	**xx**	**xx**	No association due to injury
Name Round 14	xxx	2nd grade	**30**	**14**	Usual–Usual
Name Round 15	xxx	2nd grade	**26**	**12**	Poor–Poor
Name Round 16	xxx	1st grade	**29**	**14**	Usual–Usual
Name Round 17	xxx	1st grade	**30**	**15**	Usual–Usual
Name Round 18	xxx	1st grade	**30**	**15**	Usual–Usual
Name Round 19	xxx	1st grade	**30**	**19**	Usual–Good
Name Round 20	xxx	1st grade	**30**	**8**	Usual–Poor
Name Round 21	xxx	1st grade	**27**	**8**	Poor–Poor
Name Round 22	xxxx	1st grade	**24**	**7**	Poor–Poor
Name Round 23	xxx	2nd grade	**28**	**12**	Usual–Poor
Name Round 24	xxx	1st grade	**29**	**14**	Usual–Usual
Name Round 25	xxx	1st grade	**28**	**14**	Usual–Usual
Name Round 26	xxx	1st grade	**31**	**18**	High–Good
		Median score	29.0	14.0	
High comfort (blue zone)	>30	Median $^{+\,2\text{ comfort points}}$	Good match rating (blue zone)	>15	
Usual comfort (black zone)	28–30	Median $^{\pm 1\text{ comfort point}}$ (3 point spread)	Usual match rating (black zone)	13–15	
Poor comfort (red zone)	<28	Median $^{-2\text{ comfort points}}$	Poor match rating (red zone)	<13	

Table 2b
Comfort and rated performance for a Super 14 Rugby player for 16 weeks of football.

Player	Opposition	Team	Lower limb comfort score	Match rating score	Association between comfort and match ratings
Name Round 1	xxx	1st grade	**34**	**19**	High–Good
Name Round 2	xxx	1st grade	**34**	**19**	High–Good
Name Round 3	xxx	Injured	**xx**	**xx**	No association due to injury
Name Round 4	xxx	1st grade	**33**	**19**	Usual–Good
Name Round 5	xxx	1st grade	**33**	**17**	Usual–Usual
Name Round 6	xxx	Injured	**xx**	**xx**	No association due to injury
Name Round 7	xxx	1st grade	**34**	**18**	High–Usual
Name Round 8	xxx	Injured	**xx**	**xx**	No association due to injury
Name Round 9	xxx	Injured	**xx**	**xx**	No association due to injury
Name Round 10	xxx	Injured	**xx**	**xx**	No association due to injury
Name Round 11	xxx	1st grade	**33**	**14**	Usual–Poor
Name Round 12	xxx	1st grade	**30**	**15**	Poor–Poor
Name Round 13	xxx	2nd grade	**28**	**15**	Poor–Poor
Name Round 14	xxx	2nd grade	**30**	**15**	Poor–Poor
Name Round 15	xxx	2nd grade	**30**	**14**	Poor–Poor
Name Round 16	xxx	Injured	**xx**	**xx**	No association due to injury
		Median score	32	17	
High comfort (blue zone)	>33	Median$^{+2\text{ comfort points}}$	Good match rating (blue zone)	>18	
Usual comfort (black zone)	31–33	Median $^{\pm 1\text{ comfort point}}$ (3 point spread)	Usual match rating (black zone)	16–18	
Poor comfort (red zone)	<31	Median $^{-2\text{ comfort points}}$	Poor match rating (red zone)	<16	

highlights an association between lower limb musculoskeletal comfort and performance.

4. Discussion

This has been the first study to assess the relationship between lower limb comfort rated match day performances. Rated performance measures are commonly used within professional sport to monitor tasks such as skill execution, intensity, adaptability to the game being played, and attention to game plan. The importance of performance measures for football success is based upon a player and team collectively out performing opponents. Thus measures of performance and programs to prevent and address comfort and injury may be of importance for individual and team success.

A paradigm not widely tested which is relevant to football is poor lower limb comfort will affect running and football skills which may subsequently compromise performance criterion. While it is acknowledged many factors will affect performance, it is surprising that greater attention has not been given to measures of musculoskeletal comfort and their effect on performance.

Training routines within professional football comprise a variety of different programs intended to maintain or improve fitness, to improve skills or to use as selection training. Players returning from an injury event may not be able to participate in full regular sessions, may be time limited or be required to participate in modified training drills such as “off legs” or stationary skills. The benefits derived from a modified program cannot be considered the same as participation in a full regular training session. The limited training routines will affect performance criterion needed for football skill execution.

One of the challenges for conditioning staff of football organizations is how to deal with poor lower limb comfort prior to match day events. Unlike lower limb discomfort following match day which can be modified with numerous intervention strategies such as modification of training programs, massage, medical intervention and the passage of time, there are limited intervention strategies that exist when poor lower limb comfort is identified 24 h before match day.

Past studies indicate lower limb comfort will change over the period of a training week (Kinchington et al., 2010). Lower limb comfort increases over the period of a training week and generally is higher prior to match day compared to the beginning of the training week. The end of a regular training week generally involves a taper period in which the body is not subjected to high loads of physical stress. Therefore lower limb comfort will theoretically improve and be denoted by higher end of week (match day) comfort ratings. Poor match day comfort may be due to a player sustaining an injury prior to the match day or due to lower limb weekday comfort not resetting to median or usual patterns of comfort. In this study, poor lower limb comfort had a significant association with match day rated performance (Fig. 2c; $R^2 = 0.25$). However, it is acknowledged there will not always be a perfect relationship between lower limb comfort and match ratings. Fig. 2b shows that for 250 player weeks, usual-high comfort scores resulted in poor (red) match ratings, but was not statistically significant. This was considered normal due to multiple factors affecting a player’s ability to perform well, including factors not involving the status of lower limb comfort. Data points which were not included in the final analysis due to their biasing statistical results in favour of the research hypothesis involved two players whose comfort results were outliers and whose data were not representative of the cohort because of known medical conditions. The two players recorded more than 15 poor (red zone) comfort events from a possible 18 and 20 weeks respective participation. The comfort data scores were significantly outside the upper 25% whisker range for red comfort events shown in Fig. 1. In these cases not only was poor lower limb comfort associated with poor match day rated performance scores, but also recorded poor comfort early in the training week. These players registered poor lower limb comfort consistently due to chronic degenerative lower limb musculoskeletal conditions. Such information has relevance to clinicians who deal with chronic injuries because the example provides a snapshot of the many facets of a football cohort and the many factors which will affect a players comfort and potentially subsequent rated performance. It is therefore of clinical relevance to establish tools, such as the LLCI used in this study, to monitor not only group data but also all individual players so that effective intervention strategies can be applied.

The results from this study show how lower limb comfort measures may be used as a tool to indicate the potential playing status of an individual. In this study, we showed that when a players lower limb comfort is below a median or usual comfort range, performance was compromised (60%, $P < 0.001$). However, the reverse situation is not necessarily consistent. When lower limb comfort is high, performance can still be poor; which is due to the many factors that effect performance. This information may be of assistance to athlete, coaches and conditioning staff on how to manage individuals if lower limb comfort is poor. These results are consistent with other research which indicated a state of comfort is beneficial to reduce muscular fatigue and injury (Mündermann et al., 2003; Wakeling et al., 2002).

The comfort index used in this study, which has been previously validated for injury measures, has the capacity to be used as a valid and responsive instrument to assess rated performance criteria in football. This outcome has important characteristics for future use in research and in clinical practice. The generalisability of this study is limited by the fact it was conducted with two football teams from different codes. Further, outcome results will be affected by factors such as the time comfort data is collected. Comfort will change with time (Kinchington et al., 2010). Therefore, for match day ratings lower limb comfort should be collected as close to match time as possible. In a pilot study conducted by the authors, when comfort data were collected on match day, generally 2 h before the start of the match, there was a lack of compliance by players in provision of data, the coaching staff were not supportive and comfort responses were often erroneous. Frequently, players provided an exaggerated comfort score because of psycho-physiological effects such as adrenaline and pain inhibiting agents and many did not register comfort data. The collection of data the day of the match was a significant imposition upon the players. In the current study, we collected data 24–30 h before match time and the data were reliable as shown in a previous study (Kinchington et al., 2010) with absolute differences in comfort scores between 0 and 24 h varying only between 0.21 and 0.37 comfort points. However, time periods greater than 24 h will produce significant variations in comfort scores.

The application of the methodology described in this study has relevance to other sports and also to youth and amateur sports where the level of medical care and conditioning science is not typically as good. The LLCI extends previous studies in this field by highlighting the importance of lower limb comfort to an individual in relation to perceived performance. Because the system collects prospective data on lower limb comfort, the implementation of it requires a health belief model for successful use (Conner & Norman, 1996). In a health belief model education about the negative consequences of not paying attention to lower limb discomfort need to be accepted and then the players have to want to avoid these consequences. The belief in the LLCI would then be confirmed by players using it as a means to proactively to avoid serious injuries and be detrimental to rated performance.

5. Conclusion

This study examined the hypothesis that poor lower limb comfort (red zone) as measured by the LLCI was not correlated with high match rating (blue zone rated performance). The LLCI is the first measurement tool to investigate a relationship between comfort and rated performance. The main advantages of the LLCI are its ease of implementation, the clarity of the information collected and most importantly, the direct clinical application of the information to the performance of individual players. The categorization of players into high and low comfort groups for any given week will facilitate critical clinical decisions about intervention strategies to improve player lower limb comfort prior to match day. Such decisions are likely to have a major influence on player performance.

Conflict of interest

The authors declare no conflict of interest.

Ethical approval

Ethics approval was granted from the Human Ethics Committee at Victoria University, Australia.

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