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Movement Demands in Australian Rules Football as Indicators of Muscle Damage

Authors: Warren Young¹, Jamie Hepner^{1,2}, Daniel W. Robbins³

1. School of Human Movement and Sport Sciences
University of Ballarat,
PO Box 663, Ballarat,
Victoria, Australia. 3353.
2. South Australian Sports Institute
27 Valetta Rd,
Kidman Park, SA,
Australia. 5025
3. School of Physiotherapy, Faculty of Health Sciences,
University of Sydney,
Lidcombe, NSW, Australia. 2141

Corresponding author contact information:

Daniel Robbins

Address:

School of Physiotherapy, Faculty of Health Sciences
University of Sydney
PO Box 170, Lidcombe, NSW
Australia 2141

Ph: (02) 9351 9280

Mob: (02) 0451 221 948

Fax: (02) 9351 9278

Email: daniel.robbins@sydney.edu.au

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ABSTRACT

The purpose of this study was to determine if there is an association between variables that describe movements in an Australian Rules football (ARF) game with muscle damage. Fourteen elite junior ARF players were monitored with a Global Positioning System (GPS) during a match and muscle damage was estimated by determining creatine kinase (CK) 24 h post-match. Players were median split based on CK levels into a high and low CK group, and the groups were compared with independent t-tests. The primary finding was that the group that experienced greater muscle damage (high CK group) generally covered significantly ($p < 0.05$) greater distances. This was the case for running speeds between 4-7 m.s⁻¹ and, with the exception of high acceleration, all intensities of acceleration and deceleration. The high, as compared to the low, CK group also produced a significantly greater (42 %) “player load”. All of these significant differences were accompanied by large effect sizes. Group-specific Pearson (r) correlations between CK level and GPS variables suggest that a certain volume of movement is required prior to the elicitation of a positive relationship beyond trivial or small. Correlations between CK and running speeds greater than 4 m.s⁻¹ and moderate-high acceleration and deceleration were negative in the low CK (lesser volumes) group. With the exception of low intensity acceleration/deceleration, the same relationships were positive and generally of a moderate to large magnitude in the high CK (greater volumes) group. It may be that a certain volume of movement is required in order for that movement to be strongly associated with CK levels. It was concluded that selected GPS variables obtained from ARF games can be used as indicators of muscle damage, and this information may be used to individualize recovery strategies following games.

Key words: Global Positioning System, GPS, creatine kinase, body contact, acceleration, deceleration

INTRODUCTION

Australian Rules football (ARF) is a physically demanding game which can result in signs of fatigue for up to three days post-match (2). To some extent, post-match fatigue may be related to muscle fibre damage as indicated by elevated plasma creatine kinase (CK). This marker has been shown to be significantly elevated following a rugby game, and without specialised interventions (e.g., water therapy), CK remained partially elevated after 3.5 days (5). Muscle damage as a result of playing field sports such as ARF is likely to be caused by running, body contact (13) and eccentric muscle activity when stopping from sprints and landing from jumps (10) and has been associated with performance attenuation. For example, muscle damage induced by 10 sets of 10 repetitions of vertical jumps was associated with reduced multiple 10 m sprint performance 1-2 days post-exercise (14). The presence of muscle damage following exercise may potentially impair subsequent training and competition performances.

In addition to attenuating subsequent performance, muscle damage may elevate the risk of injury. Lazarim et al. (9) suggested that playing soccer matches with extremely high levels of CK could increase the risk of injury during competition. Further, Brockett et al. (1) suggested that muscle damage consisting of micro-tears that are induced by eccentric exercise can increase the susceptibility of the muscle to a more serious tear. As injury prevention and performance level are major concerns at all levels of sport, post-exercise muscle damage deserves consideration when constructing training and competition schedules.

The demands of ARF have been quantified by video analysis of games (4) and more recently by Global Positioning System (GPS) tracking (15). The use of GPS and associated software has allowed coaches to quantify player movements using several

variables which can be reported in real time or shortly after competition. It is possible that GPS measures which describe movement demands are associated with the level of muscle damage elicited via match play. It is presently unknown which, if any, variables may be related to muscle damage as measured by plasma CK. Therefore, the purpose of this research was to determine if there was an association between GPS variables describing movement demands of an elite junior ARF game and post-match CK levels. It was hypothesised that variables which reflect eccentric muscle activity would be more strongly associated with higher, as compared to lower, CK levels.

METHODS

Experimental Approach to the Problem

Global positioning systems were used to collect data related to the movement demands of elite junior ARF match play. Creatine kinase levels were determined 24 h post-match as an indicator of relative muscle damage. Participants were median split into high and low CK groups in order to examine the association between match movement demands and muscle damage. Elucidation of the various relationships between movement demands and muscle damage will provide insight into efficacious recovery strategies.

Subjects

Fifteen male elite junior ARF players aged 16-18 years who were representing their state in the National under 18 football championships volunteered to participate in the study. Subjects were in-season and had experience with basic resistance training. The study was approved by the University Human Ethics Committee Review. Prior to the investigation, all subjects were briefed on data collection protocols, experimental

risks, equipment and the nature of the study prior to signing an informed consent document.

Procedures

The ARF match was completed in the afternoon in mild to warm conditions. Meals prior to the match and 24 h post-match were self-selected. Players were provided with unlimited water before, during and after playing to maintain a hydrated status.

As it has previously been suggested that CK may be at or near peak levels 24 h post-match (13,14), samples were taken at this time. A pinprick to the finger allowed 28.5 μL of capillary whole blood to be drawn, which was placed on a measurement strip and analysed by a Reflotron (Roch Diagnostics, Grezacherstrasse, Switzerland). It was assumed that the CK analysed emanated from muscle damage rather than cardiac or brain damage. The Reflotron was calibrated according to the recommendations of the manufacturer, and analysis took place in a controlled laboratory at 25° C.

The participating players wore a Minimax GPS unit (Catapult Innovations, Australia) operating at 5 Hz. The validity of this device has been previously determined (7). The unit was secured in a pouch in a harness and was located on the upper back of the player. Shortly after the game, GPS files were downloaded to a computer and analysed with the software provided by the manufacturer (Logan Plus Version 4.2.3). The distances covered in metres for the following speed zones were recorded: 0.1-1.9 m.s^{-1} (walking), 2.0-3.9 m.s^{-1} (jogging), 4.0-5.9 m.s^{-1} (running), 6-7.0 m.s^{-1} (fast running) and greater than 7.0 m.s^{-1} (sprinting). The distance travelled accelerating or decelerating was also recorded for high acceleration (3-15 m.s^{-2}), moderate acceleration (1-3 m.s^{-2}), low acceleration/deceleration (-1 to 1 m.s^{-2}), moderate deceleration (-1 to -3 m.s^{-2}) and high deceleration (-3 to -15 m.s^{-2}). As there

was no precedence for determining the thresholds for accelerations zones, we conducted pilot testing with one player who was required to perform maximum accelerations and decelerations from 10 m sprints. While the analysis was subjective in nature, it provided some indication of acceleration/deceleration values expected from maximum efforts.

A unique variable generated by the GPS software is “player load”, which is obtained by recordings from the in-built accelerometer in the GPS unit. This is a measure of the accumulated load based on combined three-dimensional acceleration and deceleration measurements sampled at 100 Hz. According to the manufacturer (Catapult Innovations), player load is calculated from the instantaneous rate of change of acceleration and deceleration in the forward, upward and sideward directions. That is, it measures all accelerations and decelerations in all directions. The potential advantage of this metric is that it accumulates from non-running activities such as kicking and jumping and impacts in tackles and collisions that occur throughout an ARF game. Since acceleration is proportional to force, player load may provide a useful measure of the total load applied to a player in a match.

Statistical Analyses

Inspection of the individual CK data revealed an outlier that was 23 % greater than the next highest score and 83 % greater than the group mean. This score was observed in a ruckman whose role was to be involved in stoppages and use his body to give advantage to his team in contests. Since this specialised playing role involving a high level of body contact was not typical of the average player, we chose to omit this participant from further analysis. To determine if there was an association between CK production and any of the variables describing movement demands of the game, we chose to median split the players into two groups. This produced a “high” CK

group (n=7) and a “low” CK group (n=7). A t-test for independent samples confirmed the groups were significantly different on CK ($p<0.001$, 119 %, effect size=3.23).

Independent t-tests were also performed to determine if there were any statistically significant differences in GPS variables between the groups. The magnitude of the differences in group means were described with effect sizes (ES) using Hopkins (6) thresholds: trivial, <0.19 ; small, 0.20-0.59; moderate, 0.60-1.19; large, 1.20-1.99; and very large, 2.0-4.0. Pearson (r) correlation coefficients were determined to investigate the group-specific relationships between CK and the GPS variables. Magnitudes of effect of the correlations were determined as follows: trivial, <0.10 ; small, ≤ 0.10 -0.29; moderate, 0.30-0.49; large, 0.50-0.69; very large, 0.70-0.89; and nearly perfect, 0.90-0.99 (6). All statistical analyses were performed using Statistical Package for Social Sciences (SPSS) (Version 17), and significance was set at $p<0.05$.

RESULTS

The mean $\pm$ SD results for the high and low CK groups are presented in Table 1.

There are a number of variables in which the high CK group produced significantly greater scores to the low CK group ($p<0.05$), with the single biggest difference being the distance covered performing fast running (80%, $p=0.004$, ES=1.98). Correlations between CK levels and GPS variables specific to group are presented in Table 2.

Many of the correlations elicited in the high CK group are in the opposite direction as compared to those elicited in the low CK group. Among the group-specific relationships exhibiting the greatest differences are those between CK and running, sprinting, moderate and high acceleration and high deceleration.

**** Tables 1 and 2 near here****

DISCUSSION

The high CK group achieved greater scores on all GPS variables describing ARF game movements. This suggests that greater distances covered at various speeds and accelerations and decelerations are associated with greater muscle damage. The high CK group covered a 29 % greater mean total distance than the low CK group ($p < 0.05$). Although a number of factors likely contribute to muscle damage, including walking and jogging, the results of the present study suggest that relatively high intensity running and acceleration and deceleration across intensities are relatively large contributors.

While total distance is one measure of movement demands in matches, important findings from this study are concerned with the particular variables that best distinguish the high and low CK groups. It is interesting that the distances covered at walking and jogging are only moderately greater (not significant) for the high CK group and are accompanied by group-specific correlation coefficients for which the directions and magnitudes suggest little association (i.e., greater distance covered is not associated with elevated CK release) between either measure and CK levels in both groups. In contrast, there are large statistically significant differences (accompanied by large effect sizes) between the groups for the distances covered at running ($4-6 \text{ m.s}^{-1}$) and fast running ($6-7 \text{ m.s}^{-1}$) speeds (Table 1). The greatest difference between the groups was for the distance covered between $6-7 \text{ m.s}^{-1}$ (fast running), which was 80 % ($ES=1.98$, $p < 0.05$). Further supporting the notion that high intensity running is more strongly associated with CK release are the magnitudes and directions of the correlations presented in Table 2. Specifically, the low CK group

which performed less of these types of movements (running, fast running and sprinting) presented small negative correlations, indicating a negative, if any, relationship. In fact, the direction and magnitude of the correlations observed for the low CK group suggest little association between any of the GPS variables and CK levels. It may be that the volume achieved in any of the measures was insufficient to have significant impact on CK release. Conversely, the high CK group presented positive coefficients ranging from small to large in magnitude. These results suggest that high, as compared to low, intensity running is more strongly associated with CK release and that certain volumes of such running are necessary to elevate CK levels.

A higher level of muscle damage may be caused by the combination of volume and intensity of running. For example, jogging was performed with relatively high volume in both groups, but the intensity of muscle contractions would have been low (8). Given the relatively high volumes, the intensity of the contraction (i.e., low) may help explain the strength and direction of the relationships between variables such as walking, jogging, low acceleration and deceleration and total distance and CK level. Sprinting involves very high intensity muscle contractions and ground reaction forces (8) that likely contribute to muscle damage, but the volume of sprinting was quite low (165 m for the high CK group) which may explain the lack of significant difference between groups. However, the direction and strength (positive and moderate) of the correlation coefficient between sprinting and CK observed under the high, as compared to the low (negative and small), CK group suggests some association between sprinting and CK levels given a certain volume of sprinting is achieved. The combination of moderate volume and relatively high intensity contractions associated with relatively high intensity running ($4\text{--}7\text{ m}\cdot\text{s}^{-1}$) may produce more total muscle damage.

Previous research using GPS tracking of AFL games (15) has used a 1 Hz sampling rate, which may be of limited value when attempting to track rapid changes of velocity (accelerations and decelerations) (3). As we were able to sample player position at 5 Hz, new insights into movement demands are provided. The distances covered performing moderate acceleration and deceleration and high deceleration were significantly greater for the high CK group (Table 1). Further, the two relationships exhibiting the greatest differences among groups are those between high acceleration and deceleration and CK level. Specifically, the group performing greater volumes of these movements (high CK) present very large and moderate positive correlations for high acceleration and deceleration, respectively. Conversely, the group performing lesser volumes (low CK) present small and moderate negative correlations for high acceleration and deceleration, respectively. Moderate to high intensity acceleration and deceleration are likely linked to muscle damage. It is possible that the significantly greater distance covered performing high deceleration running, as compared to high acceleration running which was not different between groups, may have more greatly influenced CK release. Although the players covered less than 200 m on average performing high deceleration, this type of running involves high intensity eccentric contractions of various muscle groups such as the quadriceps. Eccentric muscle activity is known to induce muscle damage, as measured by CK (11,12). That all three deceleration measures were significantly greater under the high, as compared to the low CK, group supports the hypothesis that eccentric muscle activity is more strongly associated with high CK levels.

Player load was significantly greater for the high, as compared to low, CK group but was weakly correlated with CK levels in either group. However, when data are pooled the correlation between player load and CK level is of a large magnitude.

The player load variable was designed in an attempt to monitor “impacts”, which in ARF would include not only impacts due to running foot strikes, but also impacts due to body contact with other players (e.g. tackles). In rugby union a very high correlation of $r=0.92$ was reported for the number of tackles in a game and CK level, (13) suggesting that body contact was the predominant determinant of muscle damage. In ARF in which there is arguably less body contact but more running, it is likely that the primary cause of muscle damage is high intensity running, high acceleration and deceleration running and running with changes of direction. Body contact is likely of secondary influence. However, the contribution of various game activities to muscle damage is likely to be quite variable between individuals, positions and games.

Of interest in the present study was whether the volume of certain GPS variables is associated with CK levels and, thus, indirectly muscle damage. Data has not been normalized to whole-game playing time or partial (e.g., game quarter) playing time as match volume, rather than density (volume/time) was investigated. Also, pre-match CK levels were not determined and therefore comment on the extent of muscle damage is impossible. Further, the presented correlations were determined using very small sample sizes and should be viewed with caution and, by nature, indicate an association only, rather than cause and effect. Nonetheless, the results of this preliminary investigation suggest that GPS variables describing player movements in ARF games are associated with post-match muscle damage. In particular, the distance covered performing running between $4\text{--}7\text{ m}\cdot\text{s}^{-1}$, moderate acceleration and moderate to high deceleration are variables best able to distinguish between players who produced relatively high CK from those who produced lower CK levels. It may be that certain levels of volume for specific movement variables are

necessary in order to influence CK levels. The results of the present study suggest that post-match GPS reporting may be used to indicate the likely muscle damage 24 h following an ARF game.

PRACTICAL APPLICATIONS

The use of GPS to predict muscle damage could be of use to coaches and practitioners in prescribing recovery practices. Based on GPS data more individualised strategies could be devised and potentially result in better subsequent performance and the prevention of injury. For example, one player covered 3,565 m of running between 4-7 m.s⁻¹, 1,036 m of moderate-high deceleration running, achieved a player load value of 1,556 and produced a CK score of 487 U.L⁻¹. With respect to the same measures, a second player achieved respective values of 1,908 m, 506 m, 657 and 125 U.L⁻¹. For the first player, more aggressive recovery strategies targeting muscle damage and/or adjustment of training loads may be required to accelerate recovery and optimise player performance for future games. Coaches able to exploit information elucidating muscle damage will be able to achieve a competitive advantage. Recovery protocols that are most effective for this purpose should be the topic of future research. The player load variable may be a potentially useful indicator of muscle damage due to a combination of running and other impact events. Prior to endorsement of this measure further research is needed to determine its validity and reliability.

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Table 1. Results for the high and low creatine kinase (CK) groups (mean $\pm$ SD).

Measure	High CK group (n=7)	Low CK group (n=7)	% difference from low	Effect size
CK (U.L⁻¹)	412.6 (67.0)	188.4 (71.5)	119***	3.23 (very large)
0.1-2.0 m.s⁻¹ (m) Walking	3,587 (570)	2,893 (1,194)	24	0.74 (moderate)
2.0-4.0 m.s⁻¹ (m) Jogging	4,727 (958)	3,675 (899)	29	1.13 (moderate)
4.0-6.0 m.s⁻¹ (m) Running	2,800 (439)	2,017 (378)	39**	1.91 (large)
6.0-7.0 m.s⁻¹ (m) Fast running	474 (77)	264 (137)	80**	1.98 (large)
7.0 + m.s⁻¹ (m) Sprinting	165 (85)	115 (74)	43	0.64 (moderate)
-1 to 1 m.s⁻² (m) Low acceleration/deceleration	9,164 (1,378)	6,595 (1,811)	39*	1.60 (large)
1-3 m.s⁻² (m) Moderate acceleration	939 (125)	683 (185)	37*	1.62 (large)
3-15 m.s⁻² (m) High acceleration	394 (81)	313 (139)	26	0.71 (moderate)
-1 to -3 m.s⁻² (m) Moderate deceleration	815 (124)	603 (165)	35*	1.46 (large)
-3 to -15 m.s⁻² (m) High deceleration	193 (35)	141 (45)	37*	1.29 (large)
Total distance (m)	12,314 (1,490)	9,543 (2,690)	29*	1.27 (large)
Average speed (m·min⁻¹)	102 (17)	92 (11)	11	0.70 (moderate)
Player load	1,519 (237)	1,070 (311)	42*	1.62 (large)

p < 0.05*; p < 0.01**; p < 0.001***

Table 2. Correlations between creatine kinase (CK) levels in the high (n=7) and low (n=7) CK groups and movement demands

	High CK	Magnitude of effect	Low CK	Magnitude of effect
Walking (0.1-2.0 m.s⁻¹)	-0.640	Large	-0.221	Small
Jogging (2.0-4.0 m.s⁻¹)	0.042	Trivial	0.105	Small
Running (4.0-6.0 m.s⁻¹)	0.598	Large	-0.183	Small
Fast running (6.0-7.0 m.s⁻¹)	0.214	Small	-0.164	Small
Sprinting (7.0 + m.s⁻¹)	0.423	Moderate	-0.279	Small
Low acceleration/deceleration (-1 to 1 m.s⁻²)	-0.255	Small	-0.065	Trivial
Moderate acceleration (1-3 m.s⁻²)	0.320	Moderate	-0.202	Small
High acceleration (3-15 m.s⁻²)	0.749	Very large	-0.258	Small
Moderate deceleration (-1 to -3 m.s⁻²)	0.201	Small	-0.195	Small
High deceleration (-3 to -15 m.s⁻²)	0.477	Moderate	-0.466	Moderate
Total distance	0.011	Trivial	-0.151	Small
Average speed	-0.309	Moderate	-0.202	Small
Player load	0.227	Small	0.083	Trivial