The effect of fatigue from Australian Rules football on postural control in the lower limb

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Abstract

Previous laboratory style research has shown that fatigue worsens postural control and proprioception at the ankle. The purpose of this research was to test the effect of fatigue due to a game of Australian Rules football has on postural control, and therefore the relevance of previous research to a sporting environment. The method of analysis was a uni-lateral standing balance test. The frequency of toe touches and therefore loss of balance over a 30 second period were calculated before and after a game. The dominant leg increased significantly from 2.65 to 4.03 (p=0.005) toe touches, whilst the non-dominant leg recorded a non-significant increase from 3.06 to 3.19 toe touches. A significant difference in the change from pre to post game was also noted between dominant and non-dominant legs (p=0.017). Effect size data supported these findings. This research demonstrates that a player becomes significantly fatigued on the dominant leg during a game of football. This may indicate an increased risk of injury on the dominant side as a player becomes fatigued during the game.

(Words: 174)

Introduction

Ankle injuries are one of the most common injuries seen in all sports, with a particularly high incidence occurring in Australian Rules football players[1]. This results in pain, disability, time away from competitive sport and potentially expensive treatment including surgery if the injury is severe. In professional competition this can also result in loss of income. It is therefore important to try and prevent these injuries from occurring. Previous research has investigated the impact of ankle bracing, prior injury, grass type of the arena and hardness of the arena surface and their relationship to injury.

Factors leading to functional instability of the ankle include joint hypermobility, muscle weakness, proprioception deficits, and variability in ankle ligament anatomy[2]. Previous studies have demonstrated that fatigue decreases proprioception[3 4]. As decreased proprioception can lead to functional instability of the ankle, it could be argued that fatigue could lead to an increased risk of injury. The simplest and most common method for assessing proprioception of the ankle is by analysing postural control. The effect of fatigue on postural control has been researched in a laboratory situation. However, this research had not previously been extended to a game of Australian Rules football.

Forestier et al.[5] reported that after isometric fatigue of the tibialis anterior muscle, the ability to match the right ankle to the same angle of plantar-flexion or dorsi-flexion with the left reference ankle, was significantly decreased compared to pre-fatigue. Johnson et al.[6] used a computerised tilt-able platform to analyse stability unilaterally, bilaterally and dynamically. After fatiguing the lower limb with an isokinetic dynamometer (similar to a stair stepper), it was shown that motor control performance was significantly worse on all three tests. The authors suggested that fatigued individuals have an increased risk of injury.

Many researchers have demonstrated via force platform analysis that fatigue results in a decrease in balance and postural control. Following isokinetically induced fatigue of the plantar-flexors, dorsi-flexors, invertors and evertors of the ankle, medial-lateral(ML) sway significantly increased during quiet stance. In addition, anterior-posterior(AP) sway significantly increased during a forward lean test. These changes returned to normal after twenty minutes recovery time[7]. Vuillerme et al.[8] found that fatigue of the plantar-flexors alone increased postural sway during bi-pedal stance. Furthermore, the researchers tested the impact of vibration. While vibration was associated with a significant decrease in postural control before fatigue, only minor changes were noticed after fatigue. The authors postulated that the central nervous system relies less upon proprioceptive information originating from fatigued muscles. The nature of the participants used in these studies was not described, other than that they were male university students. There was no reference to their level of fitness or if they were sporting participants. This information is relevant to the impact fatigue would have and also to the speed of recovery.

Lundin et al.[9] found that iso-kinetically induced fatigue to the plantar and dorsi-flexors of the ankle significantly increased the amount of ML sway. Corbeil et al.[10] only fatigued the plantar-flexors and did not record a significant increase in the amplitude of postural sway, but did report a significantly increased rate of AP oscillation in postural sway. The authors suggest that fatigue did place a higher demand on the postural control system.

Vuilerme et al.[11] found that when fatigued, postural control was significantly worse with the eyes closed compared with eyes open. Prior to fatigue, very little difference was noted. This research showed that the use of vision allowed the subjects to immediately cope with the destabilizing effect induced by muscular fatigue. Therefore to minimize variables, the current researchers had the participants close their eyes during the testing procedure.

Postural stability while standing is usually considered a good method for assessing ankle proprioception and postural control, as perturbations that naturally occur during static posture is usually corrected by ankle synergies[12]. When motor or sensory components of these mechanisms are altered or defective, body sway increases and muscle activity increases simultaneously in order to maintain balance. It is only when ankle synergies fail to maintain the line of gravity within the base of support, that the body must use hip synergies or whole body movements to maintain balance. Change in support strategies can also be used to increase the base of support to maintain balance by stepping forward, backward or sideways[12].

Whilst there is an abundance of research on ankle taping and bracing, there is very little consensus about its effect on ankle stability and postural control. Refshauge et al.[13] reported no significant difference in perception of ankle plantar and dorsi-flexion movements at any velocity between taped and un-taped ankles. These researchers also found no difference between healthy subjects and those who had previous ankle injuries. This result contradicted the research by Robbins et al.[14] who demonstrated an increase in ankle proprioception, particularly in plantar-flexion, in taped subjects. The absolute position of error in the un-taped group was greater by 35.5% after a 30 minute exercise period compared to only 2.5% worse in the taped group. Research by Bennell and Goldie[15] demonstrated a detrimental effect on postural control with the use of both ankle bracing and taping. The ML ground reaction force from the force platform and the frequency of foot touch-downs by the non-support leg while the subjects eyes were closed, were both significantly worse when external ankle support was added. These researchers suggested that limitation of ankle movement may have resulted in the poorer performance. There are many other research papers with conflicting results demonstrating a lack of consistency in the evidence on this area. Therefore in the current study participants removed all forms of ankle bracing and taping during the testing procedures performed.

There is little argument about the role of fatigue in decreasing postural control. However, the extent to which it occurs and the relative significance in a sporting environment, particularly in relation to Australian rules football, has previously been untested. Most of the current research has focused on fatiguing the ankle plantar and dorsi-flexors specifically, however these muscles are never solely fatigued in a sporting situation. Considering most injuries to the ankle occur when the joint is rapidly and uncontrollably plantar-flexed and inverted, most of the previous research has failed to fatigue the peroneal muscles which act to prevent inversion of the foot.

The aim of the current research was to assess the effect of lower limb fatigue on postural control, as occurs in a standard game of Australian Rules football. This is different to previous studies that focused on fatiguing a specific muscle group or pairs of muscle groups in a laboratory situation. Postural control was assessed by calculating the ability of the players to balance on one foot before the game (non-fatigued) and comparing this to the same ability after the game (fatigued).

Method

Subjects

Thirty-one male subjects participated in the study (age: 18-32, mean: 21). The subjects were recruited from an amateur Australian Rules football club in Melbourne. Subjects were excluded if they: had an ankle injury in the last 3 months, any other lower limb or pelvic orthopaedic condition that may affect their participation and any neurological or vestibular disorder which may affect their ability to balance. Those players who had finished the game on the interchange were withdrawn due to increased recovery time, those who played less than 50% of the game were also withdrawn as they may not have achieved a sufficient level of fatigue and the researchers felt that these participants might skew the data. Those who were injured during the game did not participate in the post-match testing. Informed consent was obtained from each subject and the research was approved by the Victoria University Faculty of Human Development Human Research Ethics Committee.

Procedure

All testing was performed on game day, immediately before and after the game, within the clubrooms of the team. One and a half hours prior to the game and before the players had completed any warm up tasks, the pre-game testing was performed. Players who required ankle taping for game play had this applied after the testing procedure was completed. Following the game, players involved in the study were asked to immediately remove any ankle taping or bracing before going to the testing area for the post-game testing.

The testing area was a flat surface with six stations side-by-side, 1.5 metres apart to allow sufficient room between participants. A video camera was used to record the data at a distance to view all six testing stations at the same time. Each station consisted of a white line 50cm long facing towards the camera for the participants to use as a reference point. Participants were tested in up to four groups before and after the game, immediately following one another.

Participants were asked to place one foot on the area marked on the floor, half the group was asked to stand on the left foot and the other half stood on the right. With their eyes closed, they were asked to balance on the one foot, with the other foot held at the level of the stance foot's medial malleolus. Participants also had to keep their hands on their hips throughout the procedure and not use them to help maintain balance. They were instructed that if they were losing balance, they were not to open their eyes or take their hands off their hips, but to touch down the other foot to regain balance. Participants were then given 5 seconds after closing their eyes to steady themselves before the testing began.

One foot was tested for thirty seconds, participants were then given ten seconds to change feet on the marked area, then the above procedure was repeated on the opposite foot. The next group of participants then followed the same procedure.

Unipedal static timed balance tests with eyes closed have been shown to be reliable (ICC=0.95)[18] and repeatable (r= 0.59-0.77)[19]. This test required the participants to stand on one foot for as long a period of time as possible. The method used in the current research was varied so that participants tried to maintain balance for the entire thirty seconds. It was hypothesised that those who lost balance early on in the testing procedure may disrupt those around them using a maximum time method. There has currently been no reliability or validity testing completed on our variation in the method of postural analysis, however, this testing procedure has been used in conjunction with a force platform analysis in a study by Bennell & Goldie[15] when investigating the effects of external ankle support on postural control. Participants were only analysed over five second periods and any toe touch downs were noted. While very similar trends were noticed between the number of toe touchdowns and poor performance on the force platform, no statistical comparison was completed.

Statistical Analysis

The video record of testing was transcribed by the researchers into number of toe touch-downs before and after the game, on dominant and non-dominant foot. The data was analysed using SPSS V12.0 software. Repeated measures t-tests test for a significant change in the same subject with an intervention between tests. Two repeated measures t-tests were used to analyse the data for pre-game and post-game results on the dominant and non-dominant legs, as well as comparing the change between the two legs. Cohen's d effect sizes were also calculated.

Results

Thirty-one participants completed pre and post-game testing. The participants were drawn from two separate games on the same day. Four participants did not complete the testing as they were injured during the game and unable to participate in the post-game testing procedure. (Appendix 1: descriptive data of the number if toe touch-downs).

Table 1: see appendix 4

Table 2: see Appendix 5

Table 3: see Appendix 6

Discussion

Results from this study demonstrate that fatigue induced by a game of Australian Rules football resulted in a significant increase in the number of toe touch downs on the dominant leg, from a mean of 2.65 to 4.03 (p=0.005) over 30 seconds. On the non-dominant leg there was not a significant increase in the number of toe touch-downs. There was a significant difference in the number of toe touch-downs between the dominant and non-dominant legs (p=0.017). The large effect size noted on the dominant leg supports these findings.

Further examination of the data demonstrated that five participants had a decreased number of toe touch-downs on the dominant foot and six had a decreased number on the non-dominant foot when fatigued. It is interesting to note that all except one of these participants was aged 19 or under. The impact of re-current ankle sprains on the older players must be considered when fatigue appears to have had more of an effect on them, by comparison with many of the younger players. However, this is an area that needs to be further investigated.

Holliday and Fernie[16] demonstrated that there was a learned effect on postural sway during bi-pedal stance after repeated trials on the same day, therefore it is feasible that a learned effect may have impacted on the results obtained in this study. It is also possible that the younger players are able to cope better with the fatiguing nature of the game and that the game at under 19 level is less fatiguing.

Emery[17] (p.499) stated 'laboratory measurement techniques for balance use costly, highly technical and often non-portable equipment and hence are not appropriate for use in a clinical setting or for research in a large field-based clinical trial'. While most studies have used a force platform as the method of analysis of postural stability of the ankle, using a football match as the method of fatigue excluded the use of a force platform as the measuring tool for this study. The analysis of data obtained from a force platform can be time consuming and only one participant can be tested at any one time. Yaggie and McGregor[7] demonstrated that after twenty minutes the fatigue effect had expired, therefore force platform analysis was inappropriate for use in the current study. Participants would have had varying levels of recovery before post-game testing could have been performed. To be able to test greater numbers of players at once, a standing unilateral toe touch down analysis was the best test available. The touch down test only picks up gross loss of balance and control at the ankle, which may also be more relevant to occasions when an injury would occur.

In the current study participants were tested as quickly as possible after the game to maximize the amount of fatigue still present and limit recovery time, however there was still a delay in the time from the field to the clubrooms. As all participants could not be tested at the same time there was also a time variation in when the participants were tested after the game. The entire procedure took about five minutes to complete for all groups after the game. This still allowed the participants being tested at the end to have more recovery time than those tested first. This was a problem which previous researchers avoided by fatiguing the participants next to the testing station and then tested them immediately after[5 10 11]. This method was not possible due to the methodology employed in the present study.

Exactly why there was such a marked difference in the effect of fatigue between the dominant and non-dominant leg is unclear, however, it may be related to the nature of Australian Rules football and the effect of kicking the ball on the dominant side. Research by Pedersen et al.[4] on shoulder position sense found a higher degree of error associated with hard exercise compared to light exercise. This was explained by previous research that indicated that the muscle spindles are disturbed by the accumulation of metabolites[3]. The high intensity associated with kicking a football may explain the variance between the dominant and non-dominant sides in the current research. It may also be possible that such a fast, high intensity event such as kicking a football could have a transient effect on the muscle spindles and their afferent output to the central nervous system. The dominant leg may also be used more in activities such as pushing off when beginning to run or jumping, both are frequent during a game of Australian rules football.

Gribble et al[20] reported that isokinetic fatiguing of the muscles acting on the hip and knee joints both significantly increased the ML sway on a force platform (p=0.05), however fatigue of ankle muscles had no significant effect. Postural sway in the AP direction significantly increased after fatigue of the muscles surrounding all three joints (p=0.02). This outcome is expected as fatigue was induced to muscles acting in the sagittal plane. The invertors and evertors that would impact on ML sway at the ankle were not fatigued. The authors concluded that the slowed response to postural change associated with fatigue puts individuals at a greater risk of injury. As our research did not test for fatigue of specific muscle groups, rather the entire lower limb, the results from the study by Gribble et al[20] correlate with the findings from the present study. While it was originally the researchers intention to test the relevance of fatigue affecting ankle stability, it is more likely that the entire lower limb may have a higher risk of injury when fatigued, particularly on the dominant side.

The present study highlights a number of areas for further research including the exact level of impact that fatigue has on postural control within our sporting populations. While a toe touch-down analysis was appropriate for a pilot study, it is suggested that force platform analysis be used in future studies. The use of a portable force platform will give more scientifically validated results, however will not solve the other difficulties of variation in levels of fatigue following the game. It will also limit the number of participants that can be tested and may therefore make meaningful statistical analysis difficult. Research investigating the correlation between the rate of injury occurrence and the dominant side would also be of value. Previous studies have focused on areas and causes of injury, however, have not incorporated the statistics or dominant versus non-dominate sided injuries.

Conclusion

A game of amateur Australian Rules football has been shown to significantly decrease postural control of the dominant leg. The fatiguing effect on the dominant leg was significantly greater than the non-dominant leg. This may predispose players to a higher risk of injury, particularly towards the end of the game when fatigue will be more likely. This should be taken into consideration particularly with players who are recovering from a previous injury and are therefore already at a higher risk of re-injury. Players who are trying to play the game without appropriate prior fitness or pre-season training are also possibly at a higher risk of injury.

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Appendix 1: number of toe touch-downs.

Participant	Dominant foot: pre-game	Dominant foot: post-game	Non-dominant foot: pre-game	Non-dominant foot: post-game
1	2	7	3	3
2	1	8	1	4
3	5	3	6	2
4	1	2	6	6
5	0	0	1	1
6	4	4	4	5
7	3	5	4	4
8	10	10	8	12
9	1	3	3	4
10	3	3	2	3
11	2	3	3	3
12	15	15	8	8
13	1	3	1	2
14	3	11	1	5
15	5	3	2	1
16	1	4	4	3
17	0	1	2	1
18	2	2	4	1
19	6	3	5	6
20	2	5	7	2
21	2	3	3	4
22	1	6	4	4
23	0	1	0	1
24	0	3	0	0
25	4	5	4	1
26	0	3	2	3
27	2	3	2	2
28	0	3	0	0
29	1	0	1	2
30	1	2	1	2
31	4	1	3	4
Mean	2.65	4.03	3.06	3.19

Appendix 2

Victoria University of Technology

Consent Form for Participants Involved in Research

INFORMATION TO PARTICIPANTS:

We would like to invite you to be a part of a study investigating the effect of fatigue on ankle stability in amateur Australian Rules Football players. On four Saturdays you will be asked to be involved in a testing procedure before and after the match. This will involve being video taped standing on one leg with your eyes closed for 30 seconds and then repeating with the other leg. Testing after the game will need to be completed within 15 minutes of the final siren.

People with the following conditions are not suitable for this study:
If you have had any history of the following symptoms, please let the examiners know and you will be excluded from the study, any history of

- fainting, blackouts or loss of consciousness
- loss of balance, vertigo, dizziness
- numbness, pins and needles or weakness of the legs
- a condition preventing normal use of your legs

Risks:
In the unlikely event that you should fall or trip during testing in this study, soft tissue injuries could be sustained. These include muscle, ligament and tendon injuries. If this occurs then the injury will be managed by R.I.C.E.R - the standard first aid procedure and referral to the VU Osteopathic Medical Clinic.

Appendix 3

Victoria University of Technology

Consent Form for Participants Involved in Research

CERTIFICATION BY PARTICIPANT

I,
of

certify that I am at least 18 years old* and that I am voluntarily giving my consent to participate in the experiment entitled: **The effect of fatigue on ankle stability in amateur Australian Rules Football players** being conducted by Victoria University of Technology at Caulfield Grammarians Football Club by:

Principal Investigator:
Co-supervisor:
Student Researcher:

I certify that the objectives of the experiment, together with any risks to me associated with the procedures listed hereunder to be carried out in the experiment, have been fully explained to me by:

and that I freely consent to participation involving the use on me of these procedures.

Procedures:

- Participants will be asked to place one foot inside the area marked on the floor, half the group will stand on the left foot and the other half will stand on the right.
- With their eyes closed they will be asked to balance on the one foot, with the other foot held at the level of the stance foot's medial malleolus (ankle). They will also have to keep their hands on their hips throughout the procedure.
- If participants are losing balance they are not to open their eyes or take their hands off their hips, but touch down the other foot to regain balance.
- Participants will be given 5 seconds to steady themselves before the testing begins, they will be audibly told when the timing begins.
- The testing will go for 30 seconds, a video recorder running so that the number of foot touch downs can be calculated in a post-testing analysis.
- Once thirty seconds has elapsed, participants will be given 10 seconds to change feet on the marked area, then the above procedure will be repeated.

(Appendix 3 cont.)

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this experiment at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed: **..** }

Witness other than the experimenter: **}** **Date: ....**

...}

Any queries about your participation in this project may be directed to the researcher (Name:). If you have any queries or complaints about the way you have been treated, you may contact the Secretary, University Human Research Ethics Committee, Victoria University of Technology, PO Box 14428 MC, Melbourne, 8001 (telephone no: 03-9688 4710).

[*please note: where the participant/s is aged under 18, separate parental consent is required; where the participant is unable to answer for themselves due to mental illness or disability, parental or guardian consent may be required.]

Appendix 4

Table 1: Mean and standard deviation of toe touch-downs before and after the game.

	Mean	N	Std. Deviation
Dominant foot: pre-game	2.7	31	3.2
Dominant foot: post-game	4.0	31	3.3
Non-dominant foot: pre-game	3.1	31	2.2
Non-dominant foot: post-game	3.2	31	2.5

Appendix 5

Table 2: Repeated measures t-test, difference in toe touch downs (post-game minus pre-game).

				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	p	Cohens-d
Dominant	1.4	2.55	0.46	0.45	2.32	3.026	0.005	0.54
Non-Dominant	0.1	1.95	0.35	-0.58	0.84	0.369	0.714	0.07

Appendix 6

Table 3: Independent t-test between dominant and non-dominant legs.

				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	p	Cohens-d
Dominant vs Non-dominant	1.3	2.78	0.50	0.24	2.28	2.519	0.017	0.45