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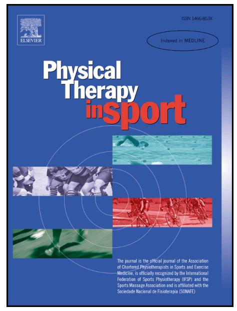

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Knee flexion strength is significantly reduced following competition in semi-professional Australian Rules Football athletes: Implications for injury prevention programs

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Knee flexion strength is significantly reduced following competition in semi-professional Australian Rules Football athletes: Implications for injury prevention programs

Running heading: Knee flexion strength is reduced following match-play in Australian Rules Football

Original paper for: Physical Therapy in Sport

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Abstract

Objectives: To evaluate strength and flexibility measures pre- and post- Australian Football (AF) competition to determine their potential utility as secondary prevention measures.

Design: Cohort study

Setting: Semi-professional AF club

Participants: Ten male AF athletes (mean ± SD; age, 21.3±2.2years; height, 186.1±6.3cm; weight, 83.5±8.6kg)

Main Outcome Measures: Maximal unilateral isometric knee flexion strength performed in 45 degrees of hip flexion and 30 degrees of knee flexion, flexibility measures of hip and knee extension and ankle dorsiflexion. All outcome measures were evaluated pre-match to determine baseline measurements and repeated acutely post-match and at 26, 50 and 74 hours following. Comparisons were made between baseline measures and all other time points.

Results: Knee flexion strength was significantly reduced at a group level acutely (-122.8N, 95%CI -156.2 to -89.4, p=0.000) and at 26 hours (-89.6N, 95%CI -122.9 to -56.2, p=0.000) following competition. Hamstring flexibility was significantly reduced at all time periods following competition (all $p<0.05$), however these values were not clinically meaningful.

Conclusions: Knowledge that unilateral isometric knee flexion strength returns to pre-competition levels by 50 hours following match-play in AF athletes is valuable for planning recovery time frames and may inform implementation of secondary prevention strategies.

Highlights:

- Maximal voluntary isometric knee flexion strength is significantly reduced at 26 hours following competitive match-play in adult semi-professional AF athletes

- Knowledge that restoration of maximal isometric knee flexion strength occurred by 50 hours post-match at the group level may be used to monitor recovery and assist in planning of subsequent training sessions
- Information regarding knee flexion strength recovery following match-play may be particularly pertinent for monitoring athletes with a past-history of hamstring strain

Keywords: Secondary prevention; athlete monitoring; hamstring strain injury

Introduction

A large body of literature has been dedicated to understanding potential risk factors associated with hamstring strain. A number of non-modifiable risk factors have been identified including increased player age, indigenous race and a past history of both hamstring and other injuries (Verrall, Slavotinek, Barnes, 2001). Other known risk factors, such as hip, knee and ankle flexibility have been reported (Bradley & Portas, 2007; Gabbe, Bennell, Finch, 2006; Witvrouw, Danneels, Asselman, 2003). Hamstring strength deficits have also been consistently identified (Orchard, Marsden, Lord, 1997), and are modifiable. However, despite this, high rates of hamstring strain have been stable and hamstring strain remains the most common and prevalent injury reported since the inception of injury surveillance in the Australian Football League (Orchard, Seward, Orchard, 2013). One reason for this might be that identified strength deficits have been reported as single measures usually conducted in the pre-season (Opar, Williams, Timmins, 2014; Orchard et al. 1997) and are unable to reflect weekly fluctuations that might occur due a variety of reasons such as the accumulation of fatigue. It has been reported that high-intensity activities are significantly reduced in the final stages of competitive match-play, across several matches for intermittent team sports (Bradley, Sheldon, Wooster, 2009; Skykes, Twist, Nicholas, 2011), possibly associated with match-induced fatigue (Black, Gabbett, Naughton, 2016).

Knowledge of weekly fluctuations of hamstring strength and lower limb flexibility profile changes throughout the in-season period, particularly in response to match-play, may contribute to a better understanding of the aetiology of hamstring injuries. It is currently uncertain as to whether potential variations may elucidate athletes at risk of injury or maladaptation to the completed workloads. In this context, routine monitoring of strength and lower limb flexibility may present an opportunity for secondary prevention (Jacobsson & Timpka, 2015). Secondary prevention is one of three sub-categories (primary, secondary and tertiary) of preventative measures aimed at preventing a specific pathology. Secondary prevention measures are implemented before pathology has caused long-term disability where sub-clinical signs of pathology may exist (Jacobsson & Timpka, 2015), in practice this refers to early detection and interventions addressing clinical signs which may result in injury.

Recently, a simple and inexpensive method of measuring isometric knee flexion strength, namely externally fixed dynamometry, has been evaluated in response to competitive match-play in junior elite soccer athletes (Wollin, Thorborg, Pizzari, 2016). Results demonstrated significant reductions in strength compared with pre-match measures immediately and at 24 hours following match-play. This is yet to be investigated in AF, where, similarly to soccer, match running volumes are large and the rate of hamstring strain is high (Bradley & Noakes, 2013; Woods, Hawkins, Maltby, 2004). Information on recovery of strength and flexibility measures following Australian Football match-play would be able to inform sports specific injury prevention practices.

The aim of this study was to evaluate the effect of competitive match-play on measures of isometric knee flexion strength and lower limb flexibility in semi-professional AF athletes. Knowledge of timeframes of recovery of knee flexion strength and ankle, hip and knee flexibility using clinically feasible tools could assist planning of training and inform implementation of in-season monitoring strategies in high-risk cohorts as a component of secondary prevention.

Methods

This study was a cohort study using repeated-measures which assessed the responsiveness of lower limb strength and flexibility measures to competitive AF match-play. Baseline measures were conducted pre-match (within four hours of the commencement of competition) and were re-assessed acutely post-match (within 30 minutes), and again at 26, 50 and 74 hours following competition.

Participants (n=10, n=20 limbs) were recruited from a single sub-elite Australian football team in the North East Australian Football League Competition, a senior, semi-professional AF competition, during the 2016 season. Each participant was provided with a detailed verbal and written explanation of the full experimental procedure. All participants provided written informed consent. This study was approved by the Australian Institute of Sport Ethics Committee (Approval Number: 20160805) and was conducted in accordance with the Helsinki Declaration. Participants were included if they were pain and injury free at the time of testing, reported no lower limb injuries in the month prior and had completed a minimum of one month of full training and match-play prior to testing. Participants were excluded if they sustained an injury during the match in question or did not participate in ≥25 minutes on the field for each of the four quarters of the match.

Prior to baseline testing, it was ensured that all participants were familiarised with the experimental procedure. Physical outcome measurements included bilateral maximum voluntary isometric contraction (MVIC) of the knee flexors and lower limb flexibility. Unilateral MVIC of the knee flexors was evaluated using an externally-fixed dynamometer and strength was recorded in Newtons (N) using a reliable protocol that has been previously described in detail (Wollin, Purdam, Drew, 2015). This test is performed with the athlete in prone with the hip in 45 degrees of flexion and the shank parallel to the ground. This protocol has demonstrated a 5% standard error of measurement (SEM) and 14% minimal detectable change (MDC) (Wollin et al. 2015). Bilateral lower limb flexibility outcome measurements included ankle dorsiflexion range of motion assessed using the knee to wall (KTW) test (Dennis, Finch, Elliot, 2008), hip extension range of motion using a modified version of the Thomas Test (MTT) (Dennis et al. 2008) and hamstring flexibility using the active knee extension (AKE) (Wollin et al. 2016) test. These tests were specifically chosen due to their identification as potential hamstring strain injury risk factors having been previously associated with hamstring strain injury in team sport populations. Both MTT and AKE were measured using a bi-level inclinometer (Isomed Inc, Kirkland WA, USA). The reliability and procedures of these tests have also been previously described in detail (Dennis et al. 2008; Wollin et al. 2016). Briefly, all three tests have previously demonstrated excellent intra-rater reliability in healthy adult populations: KTW (ICC = 0.98, SEM 0.3cm, MDC 0.8 cm) (Dennis et al. 2008), the modified MTT (ICC = 0.97, SEM 1.3˚, MDC 3.6˚) (Dennis et al. 2008) and AKE (ICC = 0.91 - 0.92, MDC 5.2-10˚) (Wollin et al. 2016).

Pre- and post-match testing was conducted at the home ground of the participants (Manuka Oval, Canberra). Immediate post-match recovery was standardised for all participants and involved ingestion of 250mL of electrolyte drink and water as desired just prior to completion of post-match testing. For the subsequent time periods following match play (26, 50 and 74hours), testing was conducted at the Australian Institute of Sport Physical Therapies Department using the same equipment and set up. All knee flexion isometric strength tests were conducted by a senior physiotherapist (PC) who was familiar with the testing procedures. All flexibility testing was conducted by a senior physiotherapist (SR) also familiar with the testing procedures. Athlete age, height and weight and lever length was collected by a trained research assistant who also recorded knee flexion strength testing results such that both the assessor and participants were blinded to the results. For flexibility testing, only the participants were blinded to the results due to logistical reasons. Participants were allocated a random order of assessment as well as random test order prior to baseline testing and this sequence was maintained for the remainder of the testing time points. The testing procedure was conducted around a single competitive match, during the in-season period.

All data was assessed for normality using the Shapiro-Wilk test and via visual inspection. All statistical analyses were performed using Stata 13 IC (*StataCorp*, *USA*). Pilot analyses indicated that an *a priori* estimate of group size indicated at least six participants were required (estimated 73N difference in effect parameters; α=0.05; β=0.20). To assess the relationship of match-play on all the strength and flexibility measurements, a linear mixed-effect model (restricted maximum likelihood [REML] regression) was fitted with time (pre, post, 26-, 50-, 74- hours) as a fixed effect for each physical measurement. A random effect for side (left or right) was fitted within participant to account for within side and participant variances. To avoid errors associated with comparisons of normalised data, raw values were utilised in the mixed model (Dankel, Mouser, Mattocks, 2016). Normalised baseline characteristics were determined for the purposes of comparison with other populations. Statistical significance was determined when the 95% confidence intervals of the fixed effects within the model did not include zero, where zero represents no change from baseline. Clinically meaningful changes for all tests were set *a priori* as KTW (>2cm change), AKE (>10° change), MTT (>10° change) and isometric knee flexion strength (>14% of group baseline, 59.7N, as this is smallest detectable change measurable by the test) (Wollin et al. 2016). These values were determined according to the SEM and MDC of each test (outlined above), whereby any observed change was required to sufficiently exceed both of these measures for it to be considered clinically meaningful. Individual responses are represented in a “profile plot” (“profileplot” command, Stata 13IC) to indicate the individual nature of the response to the competition. The use of raw values, mean change and 95% confidence intervals as well as the plotting of individual responses was based on published recommendations (Dankel et al. 2016).

Results

Ten healthy male adult semi-professional AF athletes (mean ± SD; age, 21.3 ± 2.2 years; height, 186.1 ± 6.3 cm; weight, 83.5 ± 8.6 kg) volunteered to participate in this study. Five athletes were midfield positions and five athletes were forwards/backs. The baseline measures for the group across the four tests were (mean ± SD): knee flexion strength (raw values, right 438 ± 70.6N, left 414.7 ± 86.3N, normalised, right 2.3 ± 0.3 $Nmkg^{-1}$, left 2.2 ± 0.3 $Nmkg^{-1}$), KTW (right 12 ± 2.7cm, left 11. 5± 3.3cm), AKE (right 163.7± 8.5°, left 166.4 ± 6.3°) and MTT (right 14.1± 7.7°, left 13.1 ± 8.3°).

The Shapiro-Wilk Test and visual inspections indicated that bilateral isometric knee flexion strength, bilateral KTW and right sided AKE were normally distributed and parametric statistics could be applied. The results of the linear mixed model are presented in Figure 1. Maximal isometric knee flexion strength was significantly reduced compared to baseline pre-match measures at two time periods; post-match (-122.8 N, 95% CI -156.2 to - 89.4, p=0.000) and 26 hours post-match (-89.6 N, 95% CI -122.9 to -56.2, p =0.000). No significant group changes were noted for the other time periods. KTW was significantly decreased post-match (-1.3 cm, 95% CI -2.01 to -0.54, p=0.001) compared to baseline pre-match measures. KTW was also significantly increased compared to baseline at 50 hours (1.2 cm, 95% CI 0.42 to 1.90, p=0.002) and 74 hours (1.4 cm, 95% CI 0.68 to 2.18, p=0.000) post-match. Whilst these results were statistically significant, the values were small and did not exceed clinically meaningful changes. AKE was significantly decreased at all time periods post-match compared with baseline pre-match measures. Changes from baseline ranged from -3.82° (95% CI -6.6 to -1.1, p=0.006) post-game to -4.67° (95% CI -7.4 to -1.9, p=0.001) at 74 hours post-game, and therefore were not clinically meaningful. MTT scores were significantly increased at 50 hours (5.63°, 95% CI 2.85 to 8.40, p=0.000) and 74 hours (4.83°, 95% CI 2.02 to 7.65, p=0.001) post-match compared with pre-match measures. These scores were small and did not exceed clinically meaningful changes. For all tests the responses were highly individual and are visually represented across time-periods in Figure 2.

Figure 1 Predictive margins based on mixed model statistics for all outcome measures, with 95% confidence intervals (CIs) representing effect size.

[Insert Figure 1 about here]

Footnote: *statistically significant change from baseline; #clinically meaningful change from baseline. Dashed lines represent clinically meaningful margins from baseline measures. AKE, active knee extension; MTT, modified Thomas test; KTW, knee to wall test; N, Newtons; cm, centimetres.

Figure 2 Profile plot of individual responses to competitive match-play across time points.

[Insert Figure 2 about here]

Footnote: AKE, active knee extension; MTT, modified Thomas test; KTW, knee to wall test; N, newtons; cm, centimetres.

Discussion

A significant reduction in knee flexion strength was reported acutely post-match and at 26 hours post-match compared with baseline pre-match measures. On a group level, knee flexion strength was restored to pre-match levels by 50 hours post-match. Whilst there was also a number of flexibility measures that were significantly different to baseline measures, these numbers were small and did not exceed MDC values for the tests and therefore were not considered to be clinically meaningful as determined by the *a priori* criteria.

This study has replicated the findings observed in junior elite soccer athletes following competitive match-play (Wollin et al. 2016) whereby a significant reduction in isometric knee flexion strength was measured immediately and 24 hours post-game. The current study utilised the same knee flexion strength testing protocol and equipment as Wollin et al. (2016) and was able to demonstrate similar reductions in knee flexion strength despite differences in code of football and age group. It has been shown, however that sub-elite AF matches cover greater mean total distances (13174m)[2] compared with soccer (10720m for top-class athletes) (Mohr et al. 2003), and therefore it is logical that similar if not greater strength reductions may be evident. Similar post-exercise results have also been reproduced using match-simulation running protocols and testing using isokinetic dynamometry (Greig & Siegler, 2009; Small, McNaughton, Greig, 2010; Robineau, Jouaux, Lacroix, 2012). Advantages of the isometric protocol utilised in the current study as opposed to isokinetic testing are that it is more clinically feasible for sub-elite populations being quicker, lower cost and having minimal set up requirements.

The strength reductions observed in this study immediately and at 26 hours following match-play are similar to those observed in delayed onset muscle soreness studies whereby peak torque deficits are most evident at 24-48 hours following intense eccentric exercise (Cheung, Hume & Maxwell, 2003). These deficits are most apparent for eccentric actions and less pronounced for isometric actions (Smith, 1992). Whilst this information regarding the effects of delayed onset muscle soreness has been available for decades, new information that this study provides is the nature of activity investigated and the clinically feasible methods of assessment.

At a group level, knee flexion strength had recovered to pre-match levels by 50 hours. This implies that most athletes should regain baseline isometric strength at this time and where this has not returned to baseline levels, secondary prevention strategies such as training load modification or further recovery modalities might be indicated until strength is returned. Given the association between maximal speed sprinting and incidence of hamstring strain injury (Askling, Tengvar, Saartok et al. 2007) as well as the association between large weekly volumes of high speed running and injury (Duhig et al. 2016) it may be pertinent to delay bouts of high speed running within training sessions until isometric strength has returned to baseline levels. Recovery strategies such as cold water immersion which have been shown to reduce deficits in isometric lower limb strength compared with no intervention following exhaustive team sport exercise (Ingram, Dawson, Goodman et al. 2009) could also be considered. This finding that isometric knee flexion strength had recovered to baseline measures within 50 hours following competition is also relevant when considering injury risk and congested competition fixtures. Whilst currently unknown in AF, it has been shown in professional soccer that muscle injury rates are lower when match exposures are a minimum of six days apart (Bengtsson, Ekstrand, Walden et al. 2017). Inability to recover hamstring strength in a timely manner may be especially pertinent given repeated exposures to competition and future research is required to investigate this relationship with regard to hamstring injury.

At a group level, the results of this study indicate that AKE was significantly reduced at all time-periods following match play. However, these values were small and therefore not considered clinically meaningful. The AKE test has previously demonstrated prognostic value in track and field athletes with early deficits in range of motion correlated with time to full athletic activities following hamstring strain (Malliaropoulos, Papacostas, Kiristi, 2010). Tertiary prevention is aimed at providing interventions which reduce the complications of the current pathology. These complications may be recurrent injuries, subsequent injuries of other body areas and persisting deficits that impact function (Jacobsson & Timpka, 2015). In this situation, where an athlete is in a tertiary prevention program, monitoring hamstring length using AKE following match-play may be warranted.

This study has several strengths. The protocol was time efficient and inexpensive to set-up. Combining the results of this study and previous work (Wollin et al. 2016), the generalisability of the results appears to indicate that isometric strength of the knee flexors is reduced for a period of one to two days after a single game and is not restricted to the elite sporting environment. Additionally, this study was conducted using competitive match-play and not a simulated treadmill protocol that may not necessarily replicate the demands of competition, including motivation to perform repetitive high intensity efforts and sports specific skills such as kicking. Simulated protocols have identified significant reductions as early as halftime (45 minutes) during a match (Greig & Siegler, 2009). Epidemiological evidence suggests that hamstring strains tend to occur in the latter stages of soccer matches and movement demands in AF have been shown to be reduced in the second half of match-play at both the elite and sub-elite level (Brewer et al. 2010). One limitation of this study was, however, the inability to compare external load (metres and running speed) to decrements in strength as Global Positioning System units were unavailable.

Future research should investigate the ability of the isometric knee flexion strength test as a secondary prevention program. Currently, this study has been able to show this test to be clinically feasible and sensitive to match-play in Australian Rules football. Conversely, given the large variability across days and the interaction with competition workloads, this test would appear to be inappropriate as a "once off" pre-season screening test and therefore not recommended as a primary prevention tool. Additionally, whilst there is inconsistent evidence regarding persisting deficits of isokinetic strength following hamstring injury (Maniar, Shield, Williams et al. 2016), there is emerging evidence of persisting isometric deficits (Hickey, Hickey, Maniar et al. 2017). If athletes with a history of hamstring strains have persistent deficits in isometric knee flexion strength measures this may then form a component of tertiary prevention. For example, knee flexion strength programs targeted at athletes with a past-history of hamstring strain injury could be implemented to address any identified strength deficits. Future research could also investigate whether similar results on a group level are evident over time as opposed to a single occasion of match-play and whether different teams from different levels of competition respond in the same way. Similarly, given the positional differences in total and high speed distances observed during competition in professional AF athletes (Gray & Jenkins, 2010), the potential effect of this on magnitude of strength decrements could be explored.

Conclusion

Maximal voluntary isometric knee flexion strength is sensitive to the effects of competition in semi-professional AF athletes and remains significantly reduced at 26 hours following match-play. This information highlights its potential as a component of a secondary prevention program. This information may also assist with planning subsequent training sessions following match-play especially those involving large volumes of high speed running. Testing maximal isometric hamstring strength using the methods described in this study is an efficient and relatively low cost option, however due to the variability of strength observed following competition, it is not recommended for use as a single pre-season measure for primary prevention purposes. Of the physical tests investigated, isometric knee flexion strength was the only measure to reach group clinical and statistical differences from baseline.

Conflict of interest statement

None declared.

Ethical Statement

This study was approved by the Australian Institute of Sport Ethics Committee (Approval Number: 20160805) and was conducted in accordance with the Helsinki Declaration. Participants provided written informed consent.

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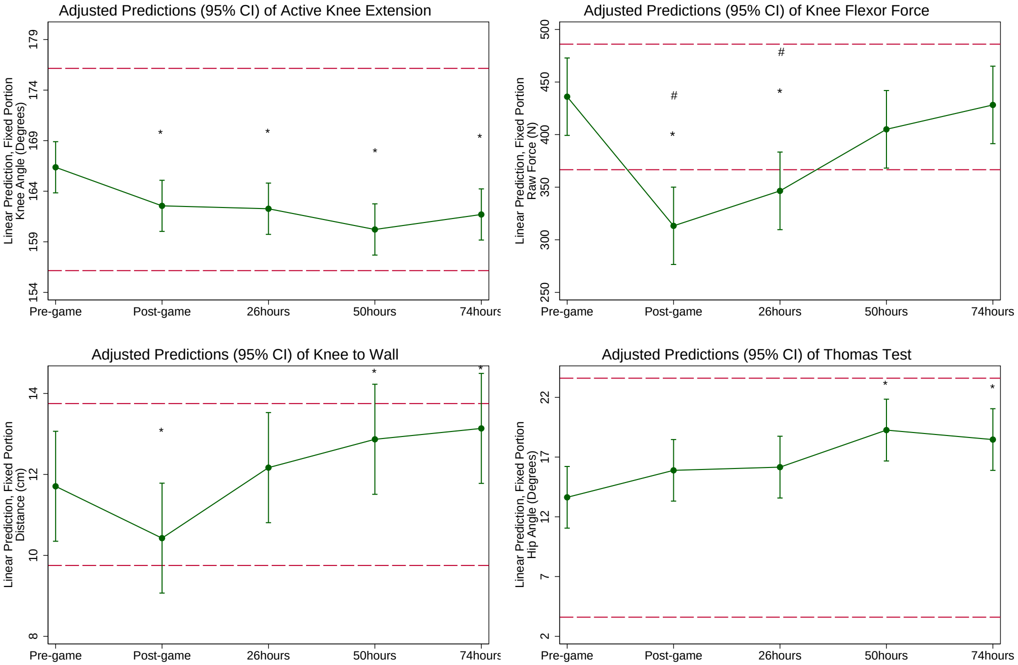
Results of physical measures across testing periods



Individual responses of physical measures across testing periods