The relationship between lower-body stiffness and injury incidence in female netballers.

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Abstract:

The aim of this study was to provide contemporary information on injury rates in an elite and sub-elite netball population and to explore the relationship between lower-body stiffness and lower-body injuries. One elite and two sub-elite teams of female netballers (n = 29) performed the vertical hop test to assess active lower-body stiffness (K_{vert}) and myometry to assess quasi-static stiffness. Lower-body injuries were monitored via self-reporting and liaison with physiotherapists. Twelve lower-body non-contact injuries were sustained by 10 players, equating to 11.29 lower-body injuries per 1000 exposure hours. The most commonly injured sites were the calf (33%) and ankle (25%). No significant differences between K_{vert} of injured and non-injured players were reported, however, injured elite players recorded significantly higher season mean quasi-static stiffness in the soleus (p = 0.037) and Achilles (p = 0.004) than non-injured elite players. Elite and sub-elite netball players recorded a higher injury incidence than previous reports of injuries in recreational netballers. Within the constraints of the study, relatively high stiffness of the soleus and Achilles appears to be related to lower-body non-contact injury incidence in female netballers, particularly at the elite level. These results provide a basis for development of injury prevention strategies.

Keywords: Myometry; Muscle mechanics; Injuries; Netball

Word Count: 197

Introduction:

The concept of stiffness describes the relationship between a force applied to a deformable material or system, and the subsequent degree of deformation. The mechanical stiffness of a muscle-tendon unit within the human body can influence injury risk for athletes (Butler, Crowell, & Davis, 2003). Previous reports have shown that too much or too little stiffness may lead to various lower body injuries including soft-tissue, joint and bony injuries occurring in non-contact situations (Bradshaw & Hume, 2012; Butler et al., 2003; Ekstrand & Gillquist, 1983; Watsford et al., 2010; Williams, Davis, Scholz, Hamill, & Buchanan, 2004; Williams, McClay, & Hamill, 2001). The relationship between relatively high stiffness and incidence of bony injuries is conceivably due to a diminished cushioning effect from stiff soft-tissues, resulting in greater stress on the bones. Higher stiffness is commonly associated with increased peak ground reaction forces leading to increased loading rates (Butler et al., 2003) and greater amounts of shock experienced in the lower extremity during running (Henning & Lafortune, 1991). Greater peak forces, loading rates and shock are associated with an increased risk of non-contact bony injuries such as knee osteoarthritis and stress fractures (Grimston, Ensberg, Kloiber, & Hanley, 1991). A retrospective study comparing high- and low-arched runners of varying ages reported that high-arched runners presented twice the number of bony injuries than their low-arched counterparts (Williams et al., 2001). High-arched runners recorded stiffer leg springs than low-arched runners (Williams et al., 2004).

When considering non-contact soft-tissue injuries such as muscle strains, individuals with higher musculotendinous stiffness may record a higher incidence rate (Wilson, Wood, & Elliott, 1991). A more compliant musculotendinous system has a greater capacity to elongate enabling external forces to be absorbed over a greater distance and time, thereby creating a cushioning effect (Roberts & Konow, 2013). This theory was supported by evidence presented in a prospective study involving 136 professional Australian football players where players who recorded higher bilateral hamstring or leg spring stiffness were at a higher risk of sustaining a non-contact, soft tissue hamstring injury (Watsford et al., 2010). In contrast, too little stiffness has also been related to excessive joint motion which places the athlete at risk of non-contact soft tissues injuries, especially ligamentous injuries of the knee (Granata, Padua, & Wilson, 2002; Williams et al., 2001; Williams et al., 2004).

Whilst these reports suggest that lower body stiffness is a contributing factor to skeletal and soft-tissue injuries, limited research exists in this area. Further, the studies involved a mixed-gender and all-male cohort. There is evidence to suggest that differences in stiffness exist between males and females, with a number of studies reporting that males presented significantly higher stiffness in the knee flexors (Blackburn, Riemann, Padua, & Guskiewicz, 2004), triceps surae (Blackburn, Padua, Weinhold, & Guskiewicz, 2006), hamstrings (Blackburn, Bell, Norcross, Hudson, & Engstrom, 2008; Granata et al., 2002) and quadriceps (Granata et al., 2002) when compared to females. To date, no research can be found that examines the relationship between stiffness and lower-body injuries in an all-female cohort.

Netball is a popular team sport for females and typically reveals a high risk of injury. Injury incidence rates are reportedly between 12 (Finch, Da Costa, Stevenson, Hamer, & Elliott, 2002) and 23.8 injuries (Hume & Steele, 2000) per 1000 match hours. Of particular concern are lower-body injuries with the most commonly injured site being the ankle joint, followed by the knee joint (Hume & Steele, 2000; Otago & Peake, 2007; Saunders et al., 2010). Most reports of injury in netball involve recreational players as opposed to elite or sub-elite players. Further, whilst there are numerous reports of high injury incidence in netballers, there are limited investigations into modifiable risk factors for injury. There is also evidence to suggest that female athletes in general are more susceptible to injury than male athletes, especially when considering lower-body injuries such as knee (Hoog, Warren, Smith & Chimera, 2016), ankle and foot injuries (Hunt, et al., 2016). Since lower-body stiffness has previously been identified as a modifiable risk factor for lower-body injury in males (Ekstrand & Gillquist, 1983; Watsford et al., 2010), it is important to explore whether this relationship also occurs in females, especially since female athletes appear to be at greater risk than male athletes of sustaining lower-body injuries. It is also important to report injury information from elite and sub-elite netballers to enable appropriate injury prevention strategies. The aim of the current study was to explore the relationship between lower-body stiffness and incidence of non-contact injuries in elite and sub-elite netballers. It was hypothesised that the netballers who sustained lower-body, non-contact injuries would exhibit different stiffness profiles than their non-injured counterparts. Results from this study will offer pertinent information for injury risk monitoring and prevention which may be useful to coaches, conditioning staff, physiotherapists and athletes.

Methods:

Participants:

Thirty-four female netballers volunteered and gave their written informed consent to participate in the study which was approved by the University of Technology Sydney Human Research Ethics Committee. Participants were included in the study if they were 18 years or over, uninjured and competing in the Australia and New Zealand (ANZ) Championships (one elite team; n=12) or NSW State League competitions (two sub-elite teams; n=22) during the 2013 season. The 34 participants included 10 centre court players, 12 defenders and 12 shooters. Teams competed in one 60 minute competition game, and one two-hour team training session per week for 14 weeks, equating to 1246 exposure hours amongst the cohort.

Procedure:

Stiffness was assessed once during pre-season and once per calendar month for the entire playing season. Exact time between assessments was dictated by player availability and varied from three to five weeks. Stiffness measurements were recorded prior to any physical activity or warm-up routines. Participant's results were included for analysis only if they completed at least three of the four stiffness assessments. Five participants did not fulfil these criteria, leaving a cohort of 29 (Age: 24.1 ± 3.2 years; Height: 1.77 ± 0.07 m; Mass: 72.4 ± 6.1 kg) including 10 elite and 19 sub-elite participants, equating to 1062.9 exposure hours amongst the remaining cohort. The remaining cohort included 8 centre court players, 10 defenders and 11 shooters. To present a robust assessment of the mechanical properties of the lower body, stiffness was assessed under active and quasi-static conditions. Preliminary unilateral comparisons of the stiffness data revealed no notable differences between limbs, thus, bilateral mean stiffness was calculated for each condition. The season mean of each stiffness measure for each participant was calculated for further assessment.

Active vertical stiffness (K_{vert}) was assessed using a validated vertical hop test. Participants hopped unilaterally in time to a metronome set at 2.2 Hz (McLachlan, Murphy, Watsford, & Rees, 2006) on a force platform (0.65 x 0.95m, Onspot, Wollongong, Australia). If the hops fell outside ±2% of the prescribed frequency, participants repeated the procedure after two minutes of rest. To eliminate any cushioning effect from footwear, hops were performed barefoot and participants were instructed to keep their hands on their hips. Once steady-state hopping was achieved ten seconds of force data sampled at 1000 Hz was collected for each leg. The force-time curves were visually inspected and three consecutive hops that were representative of the data sample were selected from each file for further analysis. K_{vert} was calculated as the ratio of peak ground reaction force to maximum centre of mass displacement during the eccentric phase of the movement, which corresponded with the mid-point of the ground contact phase (McLachlan et al., 2006). For each trial, the mean stiffness of three consecutive hops was divided by body mass to produce a score relative to individual size. The average of right and left stiffness scores was calculated to determine bilateral mean K_{vert} for each participant. Similar methodology reported excellent reliability (Ferris & Farley, 1997).

Stiffness of the lateral gastrocnemius (LG), medial gastrocnemius (MG), soleus (SOL) and Achilles aponeurosis (ACH) were measured by myometry under quasi-static (standing) conditions. Measurement sites were marked on each participant prior to data collection in accordance with SENIAM guidelines (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000). Participants stood barefoot in the anatomical position whilst measurements were collected by a hand-held myometer (Myoton-Pro, Myoton, Tallinn, Estonia). A mechanical probe was positioned over each site which delivered an impact (duration: 15 ms; force: 0.3-0.4 N) causing the tissue to briefly deform. Damped natural oscillations (Bizzini & Mannion, 2003) occurring due to the applied impact were measured by an in-built accelerometer sampling at 3200 Hz (Ditroilo, Hunter, Haslam, & De Vito, 2011). Three consecutive measurements were taken at each site in each position, giving a mean stiffness score. For each site, the average of right and left sides formed a bilateral mean stiffness score. Use of the Myoton-Pro has shown high levels of reliability (Mullix, Warner, & Stokes, 2013) and there have been reports of good construct validity for myometry (Zinder & Padua, 2011).

Participants reported injury details throughout the playing season including date, circumstances of injury, injury site, diagnosis and the consequences of the injury. For elite players, these details were provided by the team physiotherapist. However sub-elite injuries were self-reported after voluntary visits to private physiotherapists. An injury was defined as soreness during palpation, passive stretch or active contraction of the involved tissues (Crosier, Ganteaume, Binet, Genty & Ferret, 2008) and was included for further analysis in the current study if it involved soft tissues of the lower body, occurred in non-contact situations during on-court training sessions or games and resulted in the injured player being unavailable for least one game. There were no instances of any other injury classifications that may have affected the stiffness-injury analysis.

Statistical Analyses:

To evaluate the frequency and type of injuries sustained, descriptive injury statistics were calculated. These included rate of injury per 1000 exposure hours, site of injury, and physical characteristics (age, height and mass) of injured versus non-injured players. To explore the relationship between lower-body stiffness and injury incidence, various analyses were performed. An injury segmentation analysis was conducted whereby the independent variable was injury status (injured or non-injured) and the dependent variables were K_{vert} and quasi-static stiffness. A Shapiro-Wilk test was performed on all sets of data to test for normality. To determine whether any significant differences in season mean K_{vert} and quasi-static stiffness existed between injured and non-injured players, student's t-tests were performed for normal data, and Mann-Whitney U tests were performed for non-normal data. In order to calculate the magnitude of difference between the groups, measures of effect size (ES) were assessed using Cohen's *d* (Cohen, 1988). The inclusion of ES statistics ensured a robust platform for the analysis of meaningful practical differences between each level of competition. An alpha level of

$p<0.05$ was used to establish significance, and ES magnitudes were considered to be minimal (<0.30), small (0.31-0.50), moderate (0.51-0.70), or large (>0.71) (Cohen, 1988).

In addition, a stiffness segmentation analysis was performed for the independent variables of K_{vert} and the four quasi-static stiffness sites, where the dependent variable was injury status (injured or non-injured). Participants were ranked and divided via a median split method, creating equal groups of relatively stiff (STIFF) and relatively compliant (COMP) individuals. Odds ratios (OR, equation 1) and relative risk (RR, equation 2) of an injury occurring in each group were then determined to provide a detailed overview. All analyses were conducted for the whole sample, as well as for the elite and sub-elite groups individually.

$$\text{OR} = \frac{(\text{number of stiff injured} \div \text{number of stiff un-injured})}{(\text{number of compliant injured} \div \text{number of compliant un-injured})} \tag{1}$$

$$\text{RR} = \frac{(\text{number of stiff injured} \div \text{total number of stiff})}{(\text{number of compliant injured} \div \text{total number of compliant})} \tag{2}$$

Results:

From the 29 participants, 12 lower-body injuries fulfilling the injury classification criteria were recorded, equating to an incidence rate of 11.29 lower-body injuries per 1000 exposure hours. Injury sites included groin, calf, hamstrings, quadriceps, knee and ankle regions. Specific injury diagnoses were varied including strain, sprain, tear, avulsion fracture, inflammation and impingement. The most common injury site was the calf (33%) followed by the ankle (25%) and knee (17%). The 12 injuries were sustained by 10 players who formed the injured group, whilst the remaining 19 players became the non-injured group. Of the injured cohort, five were elite and five were sub-elite players, leaving five elite and 14 sub-elite players uninjured. When examined as individual groups, elite players sustained lower-body injuries at an incidence rate of 19.35 per 1000 exposure hours, whilst sub-elite players recorded 7.13 lower-body injuries per 1000 exposure hours. The physical characteristics for injured and non-injured players are displayed in Table 1.

The injury segmentation analysis of K_{vert} did not reveal any significant differences for the elite players, sub-elite players or the entire cohort (Table 2). Similarly, there were no differences for all quasi-static stiffness measurements when considering the entire cohort of participants, however, when solely considering the elite cohort, some significant differences were evident. Injured elite players possessed significantly higher stiffness in their SOL ($p = 0.037$) and ACH ($p = 0.004$) when compared to non-injured elite players (Table 2). Further, there was a tendency for higher quasi-static stiffness in the injured elite players when compared to the non-injured elite players, evidenced by moderate to large effect sizes for all muscle sites (Table 2).

A median split created two mutually exclusive groups for all stiffness parameters ($p<0.05$). Comparison of the injury incidence between COMP and STIFF for K_{vert} did not suggest that either group was at higher risk of sustaining an injury. However, a higher injury incidence was demonstrated in the STIFF when compared to COMP for quasi-static stiffness measures of ACH (OR: 3.67, RR: 2.33; Table 3). Further, when considering the elite cohort only, STIFF revealed a higher injury incidence than COMP for MG (OR: 16.00; RR: 4.00; Table 3), SOL (OR; 16.00, RR: 4.00; Table 3) and ACH (OR: 121.00; RR: 11.00; Table 3).

Discussion and Implications:

This prospective study explored the relationship between lower-body stiffness and injury incidence in one team of elite and two teams of sub-elite netballers and provided a contemporary description of injury incidence in netballers. It is the first study to prospectively monitor injuries in a group of elite and sub-elite netballers and to compare stiffness and injury incidence in female athletes. The results revealed a relationship between higher stiffness in the soleus and Achilles and lower-body injury in elite netballers. Ten of the 29 players in the study sustained a lower-body, non-contact injury equating to 34% of the sample. This is notably higher than previous injury reports in netball. Netball injury studies involving cohorts of between 3000 to 12000 recreational level players reported injured populations of 2% (McKay, Payne, Goldie, Oakes, & Stanley, 1996), 5.2% (Hopper, 1986) and 5.4% (Hopper, Elliott, & Lalor, 1995). A study involving a smaller cohort of 368 recreational players reported an injured population of 30% (McManus, Stevenson, & Finch, 2006). The injured population of 34% in the current study is greater than previous reports, particularly when considering that only lower-body, non-contact injuries were reported, whilst the aforementioned reports included injuries of any nature. The differences may be due to the higher level of competition involved in the current study when compared to previous research involving recreational athletes. Even within recreational divisions, it has been reported that A-grade players sustained more injuries than lower graded players (Hopper, 1986; Hopper et al., 1995). Thus, it is conceivable that the rate of injury incidence increases with the level of competition. This was reflected in the current results where elite players recorded an injury rate of 19.35 lower-body injuries per 1000 exposure hours, compared to 7.13 injuries per 1000 exposure hours for sub-elite players. Probable explanations for the higher rate of injury at the elite and sub-elite level include a higher weekly training load and a faster paced game than recreational players. However, it is important to note that injury reporting styles differed between elite and sub-elite players. Injuries to the elite players were recorded by a team physiotherapist, whilst sub-elite players self-reported injuries after electively seeking treatment. This difference may have impacted upon incidence rates between playing levels, however this remains an acknowledged limitation of the study. A future study with a broader population and consistent injury reporting techniques would be beneficial to confirm the relationship between training load and injury incidence.

The most commonly reported injury sites in the current study were the calf (33%), ankle (25%) and knee (17%). Previously ankle injuries were the most frequent in netballers, comprising 41% (Cassell & Clapperton, 2002), 58% (Hopper, 1986) and 84% (Hopper et al., 1995) of the injuries presented. However these reports did not classify calf injuries as a category, therefore it is likely that such injuries were classified as either ankle injuries or 'other' injuries. The ankle injury rate was lower than previous studies, which may be due to a number of factors including size of cohort, level of competition (recreational vs elite/sub-elite), difference in classification of injury site, or the mandatory practice of ankle taping/bracing at the elite/sub-elite level. Further, the injuries in previous studies were based on hospital admissions (Cassell & Clapperton, 2002) or First Aid room visits (Hopper, 1986; Hopper et al., 1995) whilst the current study was based on mandatory (elite) or voluntary (sub-elite) physiotherapist assessment.

There were no differences between the injured and non-injured groups when comparing K_{vert}. In contrast, an earlier study involving male footballers reported significantly greater K_{vert} in injured players compared to non-injured players (Watsford et al., 2010). Concurring with previous reports (Ekstrand & Gillquist, 1983; Granata et al., 2002; Watsford et al., 2010) that males possess higher levels of stiffness, the injured male athletes in the previous study presented a mean K_{vert} of 232.6 ± 19.8 N/m/kg, whilst the injured females in the current study presented a mean K_{vert} of 180.7 ± 34.0 N/m/kg. In addition, the non-injured male athletes in the previous study had a mean K_{vert} of 221.2 ± 18.6 N/m/kg, which is higher than both the injured and non-injured means in the current study. It is clear from these results and others that stiffness levels differ between the genders. It is also possible that average stiffness is affected by the nature of training and match play that different athletes are exposed to. Thus, it is recommended that further research with large cohorts be carried out to determine the normal stiffness levels in female netballers and subsequently identify the levels of stiffness that pose a risk to these athletes.

No significant differences in quasi-static stiffness of the MG or LG were evident, implying that the stiffness of the gastrocnemius is not related to lower-body injuries in netballers. In contrast, the results suggest a relationship between relatively high stiffness of the SOL and ACH and the incidence of lower-body injuries in elite netballers. Considering the elite group only, injured players had significantly higher stiffness of SOL and ACH when compared to non-injured players. These results were supported by the OR and RR statistics indicating that elite players with relatively stiff SOL and ACH should be monitored. Based on current results, the odds of an elite player sustaining a lower-body injury is 16 times higher with relatively stiff SOL and 121 times higher with relatively stiff ACH when compared to relatively compliant SOL or ACH. The stiffness of the tissues surrounding the ankle joint appears to be important when considering lower-body injury risk in elite netballers. Possible explanations for the importance of the stiffness of SOL and ACH in lower-body injury incidence include high loading of the ankle joint during cutting manoeuvres commonly performed by netballers (Vanwanseele & Smith, 2012), or repeated jumping movements. Furthermore, since musculotendinous stiffness is related to rate of force development (Wilson, Murphy & Pryor, 1994) an increase in muscle stiffness in the lower body may alter neural drive to the active musculature, changing the neuromechanical properties and possibly influencing the length-tension or force-velocity relationships, leading to an elevated injury risk. It has been documented that chronically elevated stiffness may be related to lower body injury pathologies (Bradshaw & Hume, 2012; Butler et al., 2003; Williams et al., 2004). The results of the current study suggest this relationship is a chronic mechanism, due to the relationship between season mean stiffness scores and injury incidence. Indeed, the current results do not indicate causation, rather an association between elevated stiffness and injury incidence. Further research is required to elucidate whether higher stiffness is a precursor to, or result of, injury incidence, and to examine the importance of the biomechanics of the SOL and ACH in netball injury incidence.

It is important to note that the STIFF and COMP groups are relative to the current cohort, and may not be representative of a wider population, thus, caution should be used when interpreting the findings from this cohort. A further limitation of the current study is the relatively small cohort resulting in large 95% CI ranges. Whilst the results from the current study have presented some novel relationships between stiffness and injury at the elite and sub-elite levels, further research with a larger cohort and broader range of athletes would certainly be warranted to confirm and expand on the results of the current study. Whilst it was not feasible with the cohort in the current study due to the limited sample size, it would be advisable for future research to include sensitivity analyses to provide practitioners with useful information such as negative and positive predictive values. Future research involving sensitivity analyses such as ROC curves should capture a large sample of at least 100 participants (Metz, 1978) to avoid substantial differences between the estimates and true metrics of the population (Hanczar et al., 2010).

Conclusion:

This study has provided a contemporary analysis of injury incidence rates in high level netball. The injury rates in the current study varied from previous reports based on recreational netballers, suggesting that elite and sub-elite netballers sustain more injuries than recreational netballers. Furthermore, the results of stiffness and injury analyses suggest that relatively high stiffness of the SOL and ACH is related to an increased incidence of injury, particularly in elite players. Given that stiffness is a modifiable mechanical component of the musculotendinous unit, interventions targeting a reduction in stiffness could be sought to minimise the risk of lower-body injury incidence in at-risk athletes.

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Table 1. Participant characteristics. Values are mean ± SD

	Mean Age (years)			**Mean Height (m)**			**Mean Mass (kg)**		
	Whole Group	Injured	Non-injured	Whole Group	Injured	Non-injured	Whole Group	Injured	Non-injured
All (n=29)	24.1 ± 3.2	24.1 ± 3.7	24.0 ± 3.1	1.78 ± 0.06	1.78 ± 0.04	1.78 ± 0.07	72.4 ± 6.1	73.0 ± 6.5	72.1 ± 6.0
Elite (n=10)	25.8 ± 3.8	25.8 ± 4.4	25.9 ± 3.7	1.80 ± 0.05	1.78 ± 0.04	1.81 ± 0.05	75.3 ± 5.8	75.4 ± 6.8	75.2 ± 5.4
Sub-elite (n=19)	23.1 ± 2.5	22.5 ± 2.0	23.4 ± 2.7	1.76 ± 0.07	1.77 ± 0.05	1.76 ± 0.07	70.9 ± 5.8	70.6 ± 5.9	71.0 ± 6.0

Table 2. Injured vs non-injured season mean stiffness scores, for the whole sample, and separated into elite and sub-elite groups. Values are mean ± SD.

		Whole Group (n=29)				Elite (n=10)				Sub-Elite (n=19)			
		Injured (n=10)	**Non-injured (n=19)**	***p***	**ES**	**Injured (n=5)**	**Non-injured (n=5)**	***p***	**ES**	**Injured (n=5)**	**Non-injured (n=14)**	***p***	**ES**
K_{vert} (N/m/kg)		180.7 ± 34.0	190.3 ± 52.0	0.556	0.22	186.4 ± 38.8	224.0 ± 90.4	0.418	0.58	175.0 ± 31.9	178.2 ± 25.5	0.820	0.11
Quasi-Static Stiffness (N/m)	**LG**	427.1 ± 68.6	435.3 ± 94.3	0.790	0.10	449.7 ± 75.7	389.8 ± 105.9	0.334	0.66	404.5 ± 59.8	451.6 ± 88.3	0.288	0.64
	MG	376.8 ± 43.8	384.7 ± 64.3	0.697	0.15	393.6 ± 55.0	344.1 ± 34.3	0.126	1.11	359.9 ± 23.8	399.2 ± 67.1	0.224	0.86
	SOL	621.6 ± 101.5	612.6 ± 121.5	0.835	0.08	684.5 ± 28.7	560.1 ± 115.8*	0.048	1.72	558.7 ± 111.6	631.4 ± 121.9	0.259	0.62
	ACH	642.5 ± 127.1	585.9 ± 115.7	0.257	0.47	710.8 ± 50.4	527.9 ± 90.8*	0.004	2.59	574.2 ± 148.9	606.7 ± 119.4	0.630	0.24

ES: effect size; LG: lateral gastrocnemius; MG: medial gastrocnemius; SOL: soleus; ACH: Achilles aponeurosis; *significantly different to injured group ($p < 0.05$)

Table 3. Stiffness segmentation analysis for active and quasi-static stiffness.

		Whole Group (n=29)				Elite (n=10)				Sub-Elite (n=19)			
		Compliant Group player composition	**Stiff Group player composition**	**Odds Ratio (95% CI)**	**Relative Risk (95% CI)**	**Compliant Group player composition**	**Stiff Group player composition**	**Odds Ratio (95% CI)**	**Relative Risk (95% CI)**	**Compliant Group player composition**	**Stiff Group player composition**	**Odds Ratio (95% CI)**	**Relative Risk (95% CI)**
K_{vert}		5 INJ 9 NON	5 INJ 9 NON	1.00 (0.21-4.69)	1.00 (0.37-2.70)	3 INJ 2 NON	2 INJ 3 NON	0.44 (0.04-5.58)	0.67 (0.18-2.42)	2 INJ 7 NON	3 INJ 6 NON	1.75 (0.22-14.22)	1.50 (0.32-6.94)
Quasi-Static Stiffness	**LG**	6 INJ 8 NON	4 INJ 10 NON	0.53 (0.11-2.56)	0.67 (0.24-1.86)	3 INJ 2 NON	2 INJ 3 NON	0.44 (0.04-5.58)	0.67 (0.18-2.42)	4 INJ 5 NON	1 INJ 8 NON	0.16 (0.01-1.83)	0.25 (0.03-1.82)
	MG	5 INJ 9 NON	5 INJ 9 NON	1.00 (0.21-4.69)	1.00 (0.37-2.70)	1 INJ 4 NON	4 INJ 1 NON	16.00 (0.72-354.82)	4.00 (0.66-24.37)	4 INJ 5 NON	1 INJ 8 NON	0.16 (0.01-1.83)	0.25 (0.03-1.82)
	SOL	4 INJ 10 NON	6 INJ 8 NON	1.88 (0.39-9.01)	1.50 (0.54-4.18)	1 INJ 4 NON	4 INJ 1 NON	16.00 (0.72-354.82)	4.00 (0.66-24.37)	3 INJ 6 NON	2 INJ 7 NON	0.57 (0.07-4.64)	0.67 (0.14-3.09)
	ACH	3 INJ 11 NON	7 INJ 7 NON	3.67 (0.70-19.12)	2.33 (0.75-7.23)	0 INJ 5 NON	5 INJ 0 NON	121.00 (2.02-7259.72)	11.00 (0.77-158.02)	3 INJ 6 NON	2 INJ 7 NON	0.57 (0.07-4.64)	0.67 (0.14-3.09)

INJ: injured; NON: non-injured; CI: confidence interval; LG: lateral gastrocnemius; MG: medial gastrocnemius; SOL: soleus; ACH: Achilles aponeurosis