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The influence of injury history on countermovement jump performance and movement strategy in professional soccer players: implications for profiling and rehabilitation foci.

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Abstract

Context: Professional soccer players who have sustained a lower limb injury are up to 3x more likely to suffer a re-injury, often of increased severity. Previous injury has been shown to induce compensatory strategies during neuromuscular screening tests, which might mask deficits and lead to misinterpretation of readiness to play based on task outcome measures. ***Objective:*** To investigate the influence of previous injury in professional soccer players on countermovement jump (CMJ) performance and movement strategy. ***Design:*** Cross-sectional. ***Setting:*** Professional soccer club competing in the English Championship (tier 2). ***Patients (or other Participants):*** Outfield players with a minimum 6 years as a professional. ***Intervention(s):*** Players were categorised as previously injured (n=10) or not injured (n=10). All players completed double and single leg CMJ trials. ***Main Outcome Measures:*** CMJ performance was quantified as jump height and flight time:contraction time ratio. CMJ movement strategy was quantified as force-time history differentiating eccentric and concentric phases, and CMJ depth. ***Results:*** Double leg CMJ was not sensitive to previous injury in performance or movement strategy. In contrast, single leg CMJ performance was impaired in players with previous injury who generated significantly lower eccentric and concentric peak force and rate of force development, and a deeper countermovement. Impaired single CMJ performance was also evident in the non-affected limb of previously injured players, suggesting cross contamination. Hierarchical ordering revealed that the eccentric phase of the CMJ contributed little to performance in previously injured players. In non-injured players, eccentric rate of force development and concentric peak force were able to account for up to 89% of the variation in CMJ performance. ***Conclusions:*** Single leg CMJ is advocated for player profiling, being more sensitive to previous injury and negating the opportunity for inter-limb compensation strategies. Movement strategy deficits in previously injured players suggest rehabilitation foci specific to eccentric force development.

Keywords: neuromuscular performance, previous injury, soccer, rehabilitation, profiling

The application of evidence-based practice in the context of a professional soccer club medical department relies on the clinical interpretation of player profiling that has the potential to inform practice. Sports medicine departments utilise profiling to identify players at risk of injury, and to objectively monitor the rehabilitation of injured players. The greatest risk factor for injury is previous injury with players who have sustained a lower limb injury being up to 3 times more likely to incur a re-injury,[1] which is often of greater severity than the original injury.[2] However, the influence of injury history on neuromuscular performance in professional soccer players has received little attention.[3] Hart et al. recently identified inter-limb asymmetries during bilateral countermovement jumps (CMJ) in professional players with prior injury, despite no performance deficits in jump performance.[4] Inter-limb asymmetries might reflect a compensation strategy to protect previously injured systems, and have been identified following anterior cruciate ligament injury for example.[5,6] The bilateral strength asymmetries observed in soccer players [7-9] might reflect limb dominance, but asymmetry might also be attributable to previous injury and/or limitations in rehabilitation.[10]

The influence of previous injury on bilateral asymmetry observed using double legged CMJ and using the healthy contralateral limb as a control negate the potential decline in the nonaffected limb as a consequence of the injury. Furthermore, the double legged jump enables movement compensation strategies to facilitate performance outcome,[6] with inter-limb asymmetry not impairing jump performance.[4] Movement strategy or how the movement is achieved is more insightful to the clinician in guiding rehabilitation than the outcome measure (e.g. jump height). The potential for movement compensations[5,6] suggests that double leg CMJ performance data should be interpreted cautiously when there is injury to a single limb. The single leg CMJ test might therefore provide a more valid test of limb performance and inter-limb asymmetry,[11] especially in a unilateral limb dominant sport like soccer where the primary mechanism of injury is high speed running or cutting motions where unilateral performance is fundamental. The opportunity for movement strategy compensations[5,6] during such activities provide little scope for bilateral compensations, and unilateral assessments might therefore be more sensitive to previous injury.

The aim of the present study was to assess the influence of previous injury in actively competing professional soccer players on bilateral and unilateral CMJ performance and movement strategy. Detailed analysis of the CMJ using force platforms has led to a richer appreciation of the neuromuscular profile that make up the jump.[12] The present study aimed to investigate the relative sensitivity of double and single leg CMJ performance by creating hierarchical models of those movement strategy variables influencing performance. It is hypothesized that players with an injury history will have impaired jump performance and altered movement strategies. This could provide new clinical insights for the practitioner in the club setting as they decide on their choice of profiling tests and in identifying the focus for their rehabilitation prescription.

Methods

Design

The study was conducted as a cross-sectional design, completed as part of a broader player profiling battery conducted during the competitive season within an English Championship (tier 2) club.

Participants

Group stratification was developed based on injury history. The ‘injured’ group (n=10, age 23.1 ± 7.7 yrs, weight 76.7 ± 1.4kg, body mass index 24.70 ± 2.24 kg/m^2, body fat 6.9 ± 3.5%, professional playing history 6.7 ± 7.8 yrs) comprised players that were currently fit but did have an injury history that included a significant injury to one limb only which resulted in being unable to train with the team for ≥3 months.[13] The ‘uninjured’ group (n=10, age 23.5 ± 2.1 yrs, weight 79.8 ± 2.8kg, body mass index 24.34 ± 1.22 kg/m^2, body fat 6.7 ± 0.7%, professional playing history 6.9 ± 3.5 yrs) had never sustained a lower limb injury that resulted in > 8 days lost from training and competition, and were selected from the full squad (n = 36) to reflect the demographics of the ‘injured’ group. Therefore, twenty professional soccer players from the same English Championship (tier 2) club completed the study. All participants were full time professional outfield players with a minimum of 6 years as a professional and participating in full time daily training at the time of testing.

All players provided written consent and were made aware that data would remain anonymised and would not affect their standing within the team. Ethical consent was provided by the Research Development Committee at the football club, and in accord with the Helsinki Declaration. All players were familiar with testing protocols as part of the regular administration of player profiling, with no difference between groups in this respect.

Procedures

Prior to testing all players completed an injury history form to determine their experimental grouping. All players were weighed on a Seca performance scale (model 799) and had their body fats recorded with a 7-point calibre testing procedure.[14] All testing took place between 9.30 – 10.30am, +5 days since the previous match and following a scheduled rest day. Footwear, nutritional status and a 15-minute warm-up was standardised between trials, with 7 days separating the unilateral and bilateral jump trials which were randomised in order. The warm-up included three familiarisation trials performed at 50%, 75% and 100% of maximal CMJ performance.[15,16]

The bilateral CMJ testing procedure consisted of each player performing a series of 5 jumps with 10 seconds rest between each jump. Players performed a countermovement to a self-selected depth with self-selected arm swing and were instructed to jump as fast and as high as possible.[17,18] The players were given a simple count into each jump of "3-2-1 jump" by the tester to promote reliability between trials and participants.[12]

A similar procedure was employed for the unilateral CMJ protocol. During the unilateral jump the non-test leg was off the ground and held approximately parallel to the mid-shin of the jumping leg during the jump.[19] Players rested on two legs between trials, shifting onto the test leg when the tester started the count down and cueing of "3-2-1 jump". Successive trials were alternated between limbs, with 5 trials completed on each limb.

All experimental trials were completed on a dual force plate system (PASPORT force plate, Model No: PS 2141; Pasco Roseville, CA, USA) and subsequently analysed using ForceDecks customised software package (NMP ForceDecks). Each force platform measured 0.35 x 0.35m and vertical ground reaction force was sampled at 1000Hz.

Initiation of the jump was defined by a 20N change relative to passive bodyweight,[4,20] the eccentric deceleration phase from peak negative velocity to zero velocity of the mass centre, and the concentric phase from zero velocity to takeoff.[5] Dependent performance variables were defined as jump height, calculated using flight time,[21] and the flight time:contraction time ratio.[12] Dependent movement strategy variables were defined as the peak force, rate of force development, duration, and impulse in the eccentric and concentric phases, the force at zero velocity, and the depth of the CMJ.

Statistical Analyses

A univariate general linear model was defined to investigate main effects for group (injured vs non-injured) in each of the dependent variables, for double and single leg CMJ trials. Preliminary analysis of the single leg trials included both limbs from each player, with a pooled sample therefore of n = 20 in each group. Secondary analysis accounted for the specific injury history of players in the injured group, with the affected limb considered separately to the non-affected limb, and the dominant limb differentiating trials in the non-injured group, creating n = 10 in each group. Statistical significance was predetermined at $P \leq 0.05$ and supported by partial eta squared as a measure of effect size. All assumptions associated with the general linear model were investigated, and in the secondary analysis post-hoc measures were employed to investigate main effects.

Forward stepwise regression modelling was used to determine the hierarchical ordering of force variables influencing single leg CMJ performance, investigated using both jump height and flight time:contraction time ratio. All force variables were entered into the equation, with strength of the correlation quantified as the correlation coefficient (r). Hierarchical modelling was applied to the pooled sample (n = 20) for each group, and subsequently to the reduced sample accounting for previous history and limb specificity (n = 10).

Results

CMJ Performance

Figure 1 summarises the influence of previous injury on jump height and flight time:contraction time ratio for the double leg and single leg CMJ, where the injured group is also differentiated for the injured limb. There was no significant main effect for group in the double leg CMJ in jump height ($P = 0.447$, $\eta^2 = 0.032$) or flight time:contraction time ratio ($P = 0.623$, $\eta^2 = 0.014$). However, the injured group (pooled for affected and non-affected limb) scored significantly lower in single leg jump height ($P = 0.007$, $\eta^2 = 0.176$) and flight time:contraction time ratio ($P = 0.005$, $\eta^2 = 0.188$) than the non-injured group. Secondary analysis revealed that the previously injured limb scored significantly lower than non-injured players but was not different to the non-affected limb in jump height ($P = 0.014$; $P = 0.687$) and time ratio ($P = 0.017$; $P = 0.706$).

** Insert Figure 1 near here **

CMJ Movement Strategy

Table 1 summarises the influence of previous injury on the movement strategy variables for the double leg CMJ. There was no significant difference between groups for any movement strategy variable ($P \geq 0.122$)

** Insert Table 1 near here **

Table 2 summarises the influence of previous injury, and limb status on the movement strategy variables for the single leg CMJ. Compared with the injured group (pooled, n = 20), the non-injured group elicited significantly ($P \leq 0.05$) greater peak force and rate of force development in the eccentric phase of the single leg CMJ, significantly greater force at zero velocity along with a shallower countermovement, and significantly greater peak force and rate of force development in the concentric phase which was of significantly shorter duration. Further analysis revealed that these impairments in the injured group were evident in both limbs, with the exception of countermovement depth which was significantly deeper only in the affected limb.

** Insert Table 2 near here **

Hierarchical ordering of factors influencing single CMJ performance

Table 3 summarises the hierarchical ordering of the movement strategy variables influencing performance of the single leg CMJ, quantified as the square of the correlation coefficient (r^2) at each stage. The first listed variable has the greatest individual predictive power of performance. The model is terminated when the addition of a new movement strategy variables fails to improve the magnitude of the correlation coefficient.

In the non-injured group concentric impulse and eccentric peak force were able to account for 44% of the variability in jump height, whilst eccentric rate of force development and concentric peak force accounted for 89% of variability in time ratio. In comparison, hierarchical modelling of the injured group featured only concentric phase elements. Concentric peak force and impulse accounted for 75% of variability in jump height, whilst concentric phase duration and peak force accounted for 84% of variability in time ratio. In the injured limb, concentric peak force and rate of force development accounted for 70% of variability in jump height, whilst concentric phase duration and countermovement depth accounted for 89% of variability in time ratio.

** Insert Table 3 near here **

Discussion

The aim of the present study was to investigate the influence of previous injury on the performance and movement strategy of single and double leg CMJ jumps in professional soccer players, with practical implications in profiling test selection and clinical interpretation to inform rehabilitation foci. Whilst previous research [3,4] has identified limb asymmetries in double leg CMJ, this task is subject to inter-limb compensations that might mask neuromuscular impairments in the injured limb, and soccer is largely a unilateral sport.

Sensitivity of CMJ performance to previous injury

Double CMJ performance was not sensitive to previous injury, with no difference between groups and consistent with the findings of Hart et al.[4] This comparable performance might be attributed to inter-limb compensations, since the injured group also displayed no difference in the magnitude of movement strategy variables in the double leg CMJ. Force-time history metrics in both the eccentric and concentric phases, along with CMJ depth were consistent between groups. In contrast, single leg CMJ which does not allow for movement compensations in the contralateral limb was sensitive to previous injury, in respect to performance outcomes and movement strategy. The injured group (pooled for affected and non-affected limbs) produced significantly impaired performance than the non-injured group in both jump height and flight time:contraction time ratio. Single leg CMJ is therefore advocated clinically, being sensitive to previous injury, negating the opportunity for a player to mask injury via inter-limb compensations, and providing greater functional specificity to the common mechanisms of injury.

Of note, the non-affected and affected limb in the previously injured players produced lower performance relative to the non-injured players, highlighting impaired bilateral asymmetry. This might be attributed to cross contamination of the contralateral limb as a result of physical deconditioning in the aftermath of the original injury, reflecting previous observations in bilateral movement compensations in previously injured players.[4-6] Additional contributing factors might include a lack of specific rehabilitation targeting movement strategy or early cessation of rehabilitation,[10] or, anecdotally from conversations with players, a perceived lack of capacity by the player and a reluctance to expose themselves to previously challenging movements that might be associated with pain or risk of injury. All players were pain free and competing with no daily pain, so any residuals in the results were true residuals rather than pain related abnormalities and deficits. Basing clinical decisions on performance outcomes should therefore be treated with caution, since movement strategy must be recovered in addition to performance outcome.

Sensitivity of CMJ movement strategy to previous injury

Previous injury was observed to significantly influence movement strategy in a range of force-time history metrics. The non-injured players elicited greater peak force and rate of force development in the concentric and eccentric phases of the jump. Phase duration was also lower in the non-injured players, significantly so in the concentric phase of the jump. The non-injured players produced greater force at the point of zero velocity, and a shallower countermovement depth. These movement strategy differences highlight the range of neuromuscular compromises evident in the players with an injury history, and it is these variables that offer the practitioner the greatest opportunity for enhancing rehabilitation, and ultimately reducing the risk of re-injury. These technical factors are modifiable,[22] and thus with appropriately targeted rehabilitation and exercise prescription the movement strategy can be regained. Since specific injury type, location and mechanism were not included in the group stratification, it is not possible to expand the interpretation of how specific injury mechanisms impacted upon movement strategy. With an appropriate data set this would be an interesting opportunity for future research.

Previous injury was observed to impair the concentric and eccentric phases of the single leg CMJ. Hierarchical ordering of the factors influencing single leg CMJ performance highlighted that non-injured players had primary predictors from eccentric and concentric force-time history metrics. However, players with an injury history had primary influencing factors only in the concentric phase of the jump. In the affected limb the two primary predictors of performance from the concentric phase were able to account for 70% of the variability in jump height, and 89% of the variability in flight time:contraction time ratio. This suggests that the eccentric phase is making very little contribution to task outcome in those players who have suffered a previous injury. This has clear practical implications in rehabilitation as eccentric muscular actions are commonly cited in common mechanisms of injury.[23-25] Deceleration prior to landing and cutting is a common mechanism of anterior cruciate and ankle ligamentous injury for example.[26,27] Noting the impaired rate of eccentric force development in players with an injury history, eccentric contraction of the hamstrings in high speed running is commonly cited as being the primary mechanism of hamstring strain injury and eccentric hamstring strength as the primary modifiable aetiological factor.[28] Of note these injures also suffer from high re-injury rates,[1] further highlighting the need for effective rehabilitation. These movements are also fundamental to the intermittent, multi-directional and unilateral demands of soccer. Practically, the failure of previously injured players to maximise the eccentric phase to develop performance outcomes can inform a rehabilitative focus in eccentric strength and rate of force development, in both limbs, and monitored using the single leg CMJ. Whilst double leg CMJ tests might still have value in investigating inter-limb asymmetries within a bilateral task, it should be acknowledged that bilateral tasks are relatively uncommon in the technical and physical demands of the game, or in the common mechanisms of injury. Where concerns have been raised about single leg CMJ testing in respect of the technical complexity of the test,[10] in a cohort of professional soccer players this does not present an issue.

Generalisability of findings

The current study was conducted within an English Championship professional soccer club and whilst providing high ecological validity relative to the epidemiology literature typically derived from elite soccer, generalisations beyond this specific cohort should be treated with caution and the sample size is inevitably limited by squad size.[29] Furthermore, the classification of 'injured' players whilst retaining a sample of ten did not consider specific injury types or playing position, or the time frame of the injury in relation to the testing. It would be interesting for example to investigate the specific influence of hamstring strain injury, and the duration of influence of previous injury, given the relatively high incidence and recurrence rates and the association with eccentric contractile properties. This would however require data to be pooled across clubs or a longitudinal study within the same club, both paradigms presenting a myriad of confounding variables. Performance of the players with an injury history might also be compared against base line pre-injury data as opposed to non-injured players. In this respect baseline screening of single leg CMJ performance and movement strategy will inform practice within our club. Testing and research can be challenging in a professional sporting environment and the testing in the present study was specifically designed to be player friendly. Integrating CMJ testing more frequently within the players schedule might also enhance familiarity which has been shown to decrease inter-limb asymmetries.[30]

Conclusions

Double leg CMJ performance and movement strategy was not sensitive to previous injury in a cohort of professional soccer players, with inter-limb compensation strategies masking the influence of neuromuscular deficits and reflecting the inter-limb asymmetries highlighted in previous studies.[3,4] Single leg CMJ was sensitive to previous injury both in performance outcome measures and movement strategy. Single leg CMJ testing is therefore advocated as a more efficacious test, sensitive to previous injury and more functionally specific to the physical demands and common injury mechanisms in soccer. Movement strategy deficits were observed in the concentric and eccentric phases of the single leg CMJ with implications for rehabilitation foci, but hierarchical ordering of factors influencing performance highlighted a lack of eccentric phase contribution in players with an injury history. It is suggested that the movement strategy rather than the movement outcome should be the priority in an evidence-based rehabilitation plan. Compromised or even compensatory movement strategies warrant clinical attention, even if they result in gross performance outcomes comparable with healthy baseline or normative values. Deficits in the non-affected limb of previously injured players also suggests some cross contamination of the contralateral limb which should further inform rehabilitation.

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Declaration of Interests

None reported.

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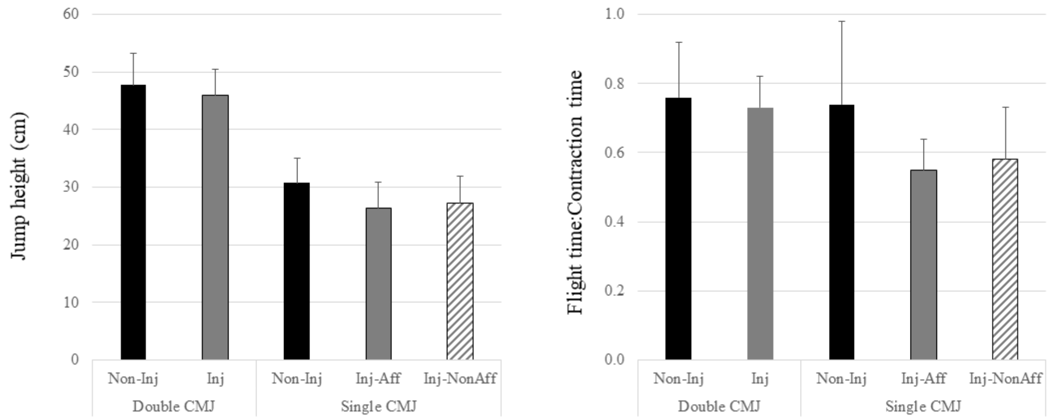

Figure 1. The influence of previous injury on CMJ jump height and flight time:contraction time ratio.

Table 1. The influence of previous injury on double CMJ force-time history metrics.

	Non-Injured	Injured	P	η^2
Ecc Impulse (N.s)	120.29 ± 30.78	129.88 ± 25.53	0.290	0.029
Ecc Peak Force (N)	807.50 ± 148.36	787.80 ± 108.05	0.634	0.006
Ecc RFD ($N.s^{-1}$)	2620.45 ± 1787.50	1946.91 ± 656.80	0.122	0.062
Ecc Duration (s)	0.18 ± 0.06	0.21 ± 0.02	0.366	0.046
Force at 0vel (N)	780.90 ± 149.42	760.90 ± 116.73	0.640	0.006
CMJ Depth (cm)	32.01 ± 9.64	37.99 ± 7.14	0.132	0.121
Con Impulse (N.s)	201.45 ± 34.06	199.27 ± 27.04	0.824	0.001
Con Peak Force (N)	963.55 ± 111.55	921.69 ± 135.99	0.294	0.029
Con RFD ($N.s^{-1}$)	1115.90 ± 742.90	992.50 ± 691.90	0.590	0.008
Con Duration (s)	0.26 ± 0.04	0.27 ± 0.03	0.628	0.013

Table 2. The influence of previous injury on single CMJ force-time history metrics.

	Non-Injured	Injured (Affected)	Injured (Non-Affected)
Ecc Impulse (N.s)	56.55 ± 16.82	65.13 ± 17.28	61.36 ± 13.43
Ecc Peak Force (N)	1352.40 ± 177.50 **	1252.30 ± 137.40	1236.80 ± 85.37 *
Ecc RFD ($N.s^{-1}$)	4327.30 ± 2838.79 **	2335.40 ± 808.10 *	2539.30 ± 859.00 *
Ecc Duration (s)	0.18 ± 0.06	0.21 ± 0.03	0.19 ± 0.04
Force at 0vel (N)	1336.75 ± 180.84 **	1213.90 ± 142.99 *	1215.60 ± 82.56 *
CMJ Depth (cm)	16.68 ± 6.83 **	22.29 ± 5.75 *	20.13 ± 4.68
Con Impulse (N.s)	170.85 ± 28,72	161.15 ± 18.70	162.46 ± 16.63
Con Peak Force (N)	1917.10 ± 282.58 **	1663.40 ± 215.06 *	1700.80 ± 180.20 *
Con RFD ($N.s^{-1}$)	4538.95 ± 3050.44 **	2257 ± 1331.61 *	2595.60 ± 1575.08 *
Con Duration (s)	0.28 ± 0.06 **	0.33 ± 0.04 *	0.33± 0.06 *

** Non-Injured significantly ($P \leq 0.05$) different to Injured (pooled n = 20);

* Significantly different to Non-Injured ($P \leq 0.05$)

Table 3. Hierarchical ordering of factors influencing single CMJ performance.

	Non-Injured (n = 20)	
	Step 1	***Step 2***
Jump Height	Con Impulse ($r^2 = 0.35$)	Ecc PkForce ($r^2 = 0.44$)
FT:CT Ratio	Ecc RFD ($r^2 = 0.78$)	Con PkForce ($r^2 = 0.89$)
	Injured (n = 20)	
	Step 1	***Step 2***
Jump Height	Con PkForce ($r^2 = 0.38$)	Con Impulse ($r^2 = 0.75$)
FT:CT Ratio	Con Duration ($r^2 = 0.77$)	Con PkForce ($r^2 = 0.84$)
	Injured & Affected (n = 10)	
	Step 1	***Step 2***
Jump Height	Con PkForce ($r^2 = 0.47$)	Con RFD ($r^2 = 0.70$)
FT:CT Ratio	Con Duration ($r^2 = 0.71$)	CMJ Depth ($r^2 = 0.89$)