

Clegg Hammer Measures and Human External Landing Forces: Is There A Relationship?

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Abstract. Ground hardness is deemed an important consideration for player safety for sports played on natural turf surfaces. Currently, a ground hardness measure is being determined using a Clegg hammer, with the suitability for play dependent on an acceptable reading. This study aimed to examine whether a relationship between Clegg hammer readings and ground reaction forces (GRF's) generated by a human during a drop landing exist.

Fifteen male community level Australian football players were recruited for the study. Participants performed a single leg drop landing on the right leg from a 45cm box onto the force plate to record GRF's. Ten trials were conducted for three conditions: no shock pad, thin shock pad (15mm) and thick shock pad (50mm) under a synthetic turf sample. Four consecutive Clegg hammer readings were recorded following each set of ten trials. Variables of interest were maximum vertical GRF (Max vGRF), maximum rate of loading (Max RoL) and Clegg hammer (CH) readings. Pearson's Correlation Coefficient was conducted to examine the relationship between variables and conditions.

Slight to fair relationships were found between the Max vGRF and any of the four CH drops ($0.181 \leq r \leq 0.189$; $p \leq 0.01$). This finding was similar to the relationship with Max RoL ($0.209 \leq r \leq 0.217$; $p \leq 0.01$). When analysed for the specific shock pad condition, the relationships remained poor ($r < 0.1$; $p \geq 0.29$), with the exception of the Max RoL and the CH readings on the thick shock pad ($0.1 \leq r \leq 0.2$; $p \geq 0.03$).

The results of this study show that the ground reaction forces experienced by a human on different levels of surface hardness are significantly different to the forces on impact of the Clegg hammer. Consequently, the Clegg hammer may not be the most appropriate device for relating surface hardness to player safety, thus it is possible that the Clegg hammer alone is insufficient in globally determining ground safety.

Keywords: Clegg hammer, landings, sport surface

1. Introduction

The hardness of a natural turf surface is an important consideration in player safety, particularly in sports where player-surface interactions are an integral part of the game. Currently, a component of natural turf ground assessment is a ground hardness measure, with the suitability for play dependent on an acceptable Clegg hammer reading.¹ Whilst the Clegg hammer has been adopted as a useful tool for measuring ground hardness in the agronomic world,^{2 3} to date however, it is unknown how the Clegg hammer readings relate to external loading during human landings, as measured by force plate data. It is possible that drawing conclusions from a mechanical device to represent the external loading forces of a dynamic system is erroneous.

The Clegg hammer consists of a rigid compaction hammer fitted with an accelerometer that is guided through a vertical tube to measure deceleration on impact in gravities (g). The Clegg hammer is used to assess the strength/stiffness of the surface (<http://www.clegg.com.au/>) and therefore when linking injury risk to this measure it is reasonable to assume that if compaction is low, then so will the force absorption capacity of the surface. A 'harder' surface is represented by a higher Clegg hammer value, with values greater than 200g suggested to significantly increase the risk of sustaining an injury, including a life-threatening head injury.⁴ A study by Aldous et al.,¹ examined player perceptions in the Australian Football League and found that Clegg hammer readings exceeding 115g were classified as a non-preferred range of hardness by the

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players.

The human however, is a far more complex dynamic system than the Clegg hammer. Comparatively, the human on landing is capable of multiple energy absorption strategies via hard and soft tissue structures to attenuate forces. Typically, ground reaction forces (GRF) are used as a measure that represents the resultant external loading forces sustained by the body.^{5 6} Anecdotally, there seems to be a perception that if the Clegg hammer reading is high, then a player will generate higher forces on landing and therefore is at greater risk of lower limb injury. It is understood that as surface characteristics change (ie. harder or softer) so may the internal or external loading of structures that may reach an injury-sustaining threshold. What remains unknown is whether a common measurement of external loading (GRF) represents results attained from a Clegg hammer which is being used to inform decisions about player safety.

Research associating ground hardness with increased injury risk exists across multiple sports.^{7 8} While an association between ground hardness and increased injury risk is evident, it seems unclear exactly why this association exists, albeit it is potentially a multi-factorial and complex interaction. Various authors have acknowledged the potentially confounding factors that may result in this association including grass type, shoe-surface interaction, climatic conditions and changes to the speed of game play.^{7 8 9} Thus when assessing ground hardness and associating this with injury risk, it is important to understand what factor/s are being assessed and their relevance to injury under what seems to be an umbrella term of 'ground hardness'.

Evidence linking GRF and lower limb injury has found that the rate of loading on impact better distinguishes between injury risk than the magnitude of GRF.^{6 10} While the Clegg hammer readings are based on accelerometer data and GRF measures taken from piezoelectric sensors based on an electromechanical system that react to compression, theoretically the two measures should be comparable as $\text{force} = \text{mass} \times \text{acceleration}$, in particular, the potential for a linear relationship. To date however, no-one has investigated whether the ground reaction forces during a human landing vary relative to the ground hardness, as measured by a Clegg hammer. In Australia specifically, it is known from communication with sporting bodies and Local Government Authorities (LGA) that the decision to close sporting grounds comprises player safety, where grounds are closed when Clegg readings exceed 120g. While evidence exists that the practice of determining sporting ground safety by LGA is lacking and requires attention,¹¹ so does the need for evidence on which to base policies/guidelines. Without this information, informed decisions cannot be made by policy makers regarding when a sports ground may be deemed unsafe for play. It is possible that Clegg hammer readings may be insufficient or inappropriate in globally determining ground safety as the device only takes into account ground hardness that may not reflect injury-risk to a player.

With this in mind, the aim of this paper was to identify whether there is a relationship between Clegg hammer readings and the GRF's generated by a human during a drop landing. It was hypothesized that there would be a poor relationship between Clegg hammer readings and GRF measures (magnitude and rate of loading) when performing a drop landing task, irrespective of the surface hardness. It was expected that as Clegg hammer readings increase relative to surface hardness, GRF measures would remain relatively consistent due to human capacity to attenuate forces.

2. Methods

Fifteen male community level Australian football players were recruited for the study. The inclusion criteria used were a minimum of five years playing experience and no lower limb injury history in the previous six months. The participants had a mean age of 21 ± 2.7 years, a mean playing experience of 7 ± 2.3 years, mean height 180 ± 6 cm and mean body mass of 80 ± 12.5 kg. Ethics approval was granted through the University of Ballarat Human Research Ethics Committee and written informed consent was received from all participants.

To replicate a sport surface and manipulate surface hardness, a configuration of a synthetic turf sample with no shock pad, thin shock pad (15mm) and thick shock pad (50mm) were used over the force plate during testing. Participants attended a two hour testing session in pairs to allow for recovery time between trials. Participants were instructed to perform a single leg drop landing on the right leg from a 45cm box onto the force plate to record ground reaction forces (Fig 1a). Ground reaction force data were collected using the 9287- 900 x 600mm with piezo-electric cells, Kistler force platform. The force plate was covered with a 60cm by 90cm synthetic turf sample. Ten trials were conducted for three conditions that included no shock pad, a thin shock pad and a thick shock pad under the synthetic turf sample. Conditions were randomised and participants were blinded to the shock pad status during the trials. Following each set of ten trials, the

synthetic sample was checked for infill disruption and adjusted where necessary. Subsequent to each set of ten trials for each participant, four consecutive drops of the Clegg hammer were recorded. The Clegg hammer used was a 2.25kg hammer fitted with an accelerometer released from 45cm through a vertical guide tube (Fig 1b).

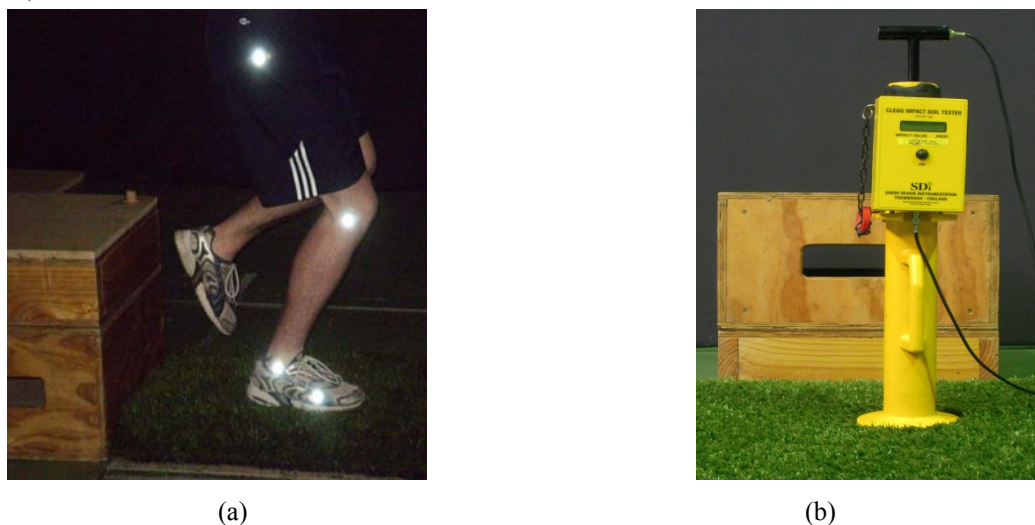


Fig. 1: (a) Experimental set up with human landing (b) Experimental set up using Clegg hammer.

All kinetic data were processed using the Peak Motus® version 9 software. Data were then entered into Microsoft Excel spreadsheet and exported to Statistical Package for the Social Sciences (SPSS) version 16 for analyses. Maximum vertical GRF (Max vGRF) in Newtons (N), maximum rate of loading calculated from the vGRF (Max RoL) in Newtons per second (Ns) and each of the four Clegg hammer (CH) readings in gravities (g) were used for analysis. As data was normally distributed, Pearson's Correlation Coefficient was conducted initially to examine the relationship between Max vGRF and CH readings, and Max RoL and CH readings. Additional correlation analysis was undertaken to establish the contribution of shock pad condition to these relationships. Subsequent t-test analyses were also conducted to ascertain whether differences between conditions and variables existed. For all analyses, alpha levels were set at $p \leq 0.05$.

3. Results

The Max vGRF, Max RoL and CH means and 95% Confidence Intervals (CIs) across the fifteen subjects for each shock pad condition are presented in Table 1. The inclusion of a shock pad resulted in a decrease in mean value for all three variables. An increase in the hardness on impact between the four consecutive CH drops was more obvious without a shockpad where it increased by 2-7 g between drops but it remained more constant on both shock pads (Table 1).

The likely strong relationships between the four consecutive CH drops were ascertained ($0.991 \leq r \leq 0.996$; $p \leq 0.00$). Only slight to fair, yet significant relationships were found between the Max vGRF and any of the four CH drops ($0.181 \leq r \leq 0.189$; $p \leq 0.01$). This finding was similar between Max RoL and any of the four CH drops ($0.209 \leq r \leq 0.217$; $p \leq 0.01$). When analysed for the specific shock pad condition (Table 2), the relationships remained poor ($r < 0.1$; $p \geq 0.29$), with the exception of the Max RoL and the CH readings on the thick shock pad ($0.1 \leq r \leq 0.2$; $p \geq 0.03$).

In light of these findings, subsequent t-test analyses were conducted to ascertain whether differences between conditions and variables existed. Results yielded a significant difference between all four Clegg hammer measures ($p < 0.05$) across all three shock pad conditions, with a consistent decrease in all measures from no shock pad to thick shock pad (Table 1).

The Max vGRFs were significantly different between the landings on the thick shock pad and both the thin and no shock pad conditions ($p < 0.05$), but not between the thin and no shock pad ($p = 0.74$). The Max GRF was less on the thick shock pad, with a mean difference of 302.7N between the thick and no shock pad, and 232.3N between the thick and thin shock pad.

Table 1: Summary of means and 95% CIs for Max vGRF(N), Max RoL(Ns) and CH(g) drops across all subjects (N=15) for each shock pad condition.

	No Shock pad		Thin Shock pad		Thick Shock pad	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
Max GRF(N)	3196	3103-3290	3121	3018-3224	2889	2816-2962
Max RoL(Ns)	233751	211659 – 255842	204231	186246 – 222215	159014	147179 – 170849
CH Drop 1(g)	149	144-153	84	82-85	54	53-54
CH Drop 2(g)	156	151-161	88	86-88	56	55-56
CH Drop 3(g)	160	154-164	88	87-89	57	56-57
CH Drop 4(g)	162	157-167	89	87-89	57	56-57

Similar to the Max GRF, the Max RoL was also significantly different between the landings on the thick shock pad and both the thin and no shock pad conditions ($p < 0.05$), but not between the thin and no shock pad ($p = 0.063$). The Max RoL were less on the thick shock pad, with a mean difference of 74736.8 Ns between the thick and no shock pad, and 45216.6 Ns between the thick and thin shock pad.

Table 2: Correlation results between Max vGRF, Max RoL and CH drops across all subjects (N=15) for each shock pad condition.

		Max vGRF	Max RoL	CH Drop 1	CH Drop 2	CH Drop 3	CH Drop 4
no shock pad	Max vGRF (N)	1	0.654**	-0.021	0.009	-0.026	0.010
	Max RoL (Ns)	0.654**	1	-0.087	-0.060	-0.086	-0.078
thin shock pad	Max vGRF (N)	1	0.651**	0.007	0.047	0.026	-0.001
	Max RoL (Ns)	0.651**	1	0.086	0.088	0.065	0.044
thick shock pad	Max vGRF (N)	1	0.543**	0.069	-0.012	0.002	-0.006
	Max RoL (Ns)	0.543**	1	-0.112	-0.166*	-0.171*	-0.175*

Note: ** correlation was significant at 0.01 level.

4. Discussion & Conclusion

This study aimed to ascertain whether drawing conclusions from a mechanical device to represent the external loading forces experienced by the human is potentially erroneous. Overall the results indicate that when examining Max vGRF or Max RoL compared with CH readings, only slight to fair relationships between the variables exist. Therefore it cannot be substantiated that Clegg hammer measures reflect external loading forces when landing, as measured by force plate data.

As hypothesized, irrespective of surface hardness, there would be a poor relationship between CH readings and GRF measures when performing a drop landing task. This was proposed due to the fact that the human is a complex dynamic system when compared to the mechanical construct of the Clegg hammer. Of interest however, is that mean values for each measure increased as surface hardness increased, however not

similarly between the GRF's and CH, which may explain the existence of the slight to fair relationships.

When looking specifically at the relationship between the GRF measures and CH readings for each shock pad condition, relationships were still unremarkable. It was proposed that CH readings would increase as surface hardness increased, but GRF's would remain consistent as a result of the human capacity to attenuate forces and adjust their landing strategy accordingly. The results did reveal that significant differences existed for the CH readings across the various shock pad conditions, indicating that the CH is reliable in differentiating between surface hardness. While the GRF measures did not respond similarly to the CH measures, Max vGRF and Max RoL measures were shown to be able to discriminate between the softer and harder surfaces, but not between the thin shock pad and no shock pad conditions. These findings are important as they show that the GRF measures do vary in accordance with surface hardness. Fundamentally, these findings indicate that the Clegg hammer readings do not relate to external loading during human landings. The results also confirm that the human is likely to be altering their landing strategy in response to the forces imposed. It has also been shown however, that a threshold between a softer and harder surface exists at which point significant differences in GRF's occur.

Yeow et al.¹² found that as landing height increased, so did peak VGRF concurrent with a hip-dominant energy dissipation strategy. These findings support the notion that as impact forces increase, changes within energy attenuation strategies occur. The current study however manipulated the surface hardness and kept landing height the same, showing that either landing height or surface hardness impacts landing strategies. It has been postulated that game characteristics such as speed of play may alter in accordance with playing surface and subsequently the nature of injuries sustained.^{9 13} Based on the current findings, if a surface remains "harder" a player may be less inclined to jump as high and render themselves susceptible to higher landing forces. However based on the suggestion from Andresen et al.⁹ and Orchard,¹³ this may reduce one injury risk but the consequences of the harder ground may alter game characteristics and hence the nature and risk of injuries sustained. Future research could investigate kinematic and internal loading variables to determine whether a sporting posture associated with landing on a harder or softer surface may be linked with known injury risk factors before conclusions can be drawn regarding which surface may be "safer" for sports play.

Further insight into the human landing response to harder and softer surfaces may be explained by Boyer and Nigg¹⁴ who proposed that muscle activity is tuned in response to impact forces to minimise soft-tissue vibrations. This muscle tuning paradigm suggested that as impact forces on the human change, the body adapts to attenuate these vibrations.^{15 16} Results of the current study found that a level of hardness between the thick and thin shock pad conditions used in this study results in a change in landing strategy, however this did not change significantly as the surface got harder (no shock pad). It may be possible that an impact threshold may exist at which point, notable differences in landing strategies exist. Overall, until the landing strategies and associated injury risk is known in response to playing surface hardness; it is erroneous to draw conclusions from a mechanical device such as the Clegg Hammer regarding player safety during landings.

Limitations

This study aimed to identify the applicability of using a mechanical device to assume external loading forces and thus possible injury risk when determining suitability for a playing surface. While player safety when determining the suitability of a playing surface should be of paramount importance, so is understanding the applicability of the device used to inform that decision. However, a limitation of the current study is that internal loading of body structures was not measured. It may be reasonable to assume that as surface characteristics change so may the internal loading of structures that may reach an injury-sustaining threshold, particularly in lieu of results that suggest that landing strategies do alter based on surface hardness. Kinematic investigation was also not included in this study and may inform whether a sporting posture associated with landing on a harder or softer surface may be linked with known injury risk factors.

In addition, this study examined GRF measures during a single drop landing, the execution of functional activities, for example, a run up and land or change of direction activity may render different results due to neuromuscular activity and loading status prior to the landing.

Conclusion

The Clegg hammer is currently being adopted to assess ground hardness of natural turf sport playing surfaces with results being used to inform decisions about player safety. While player safety may include a number of considerations, this paper aimed to ascertain whether drawing conclusions from a mechanical

device to represent the external loading forces experienced by the human is potentially erroneous. The results of the current study have shown that the Clegg hammer is a valid tool for discriminating between different levels of surface hardness; however this is not reflective of the loading characteristics expressed in a human. It is possible that the Clegg hammer alone is insufficient in globally determining ground safety and future decisions relating to the suitability of a playing surface comprising player safety made need reviewing. Future research needs to investigate kinematic and internal loading variables in response to surface hardness in conjunction with epidemiological-based research of injury patterns before conclusions can be drawn regarding which surface may be “safer” for sports play.

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