

SUMMARY

A single leg (drop) jump landing task is often used to assess functional performance. Subjects jump from a box or to a certain height, land on one foot, and stabilize as quickly as possible. In this thesis, we evaluated whether this test is suitable as part of an injury screening programme with regard to lateral ankle sprains in elite footballers.

In **chapter 1**, we provided an introduction to lateral ankle sprains, consisting of a brief overview of incidence, anatomy, mechanism, risk factors, and prevention. Furthermore, the importance of functional testing and outcome measure selection was emphasized.

In **chapter 2**, we evaluated which dynamic tests and force plate outcome measures are most sensitive to differences between and within groups with regard to foot and ankle pathology. In this systematic review and meta-analysis, we included 35 studies. Results were subdivided by test category: walking, running, landing, sideways, and gait termination. The 'landing' test detected differences due to ankle instability, with 'time to stabilization in anteroposterior direction' as a relevant outcome measure.

In **chapter 3**, we aimed to assess whether the static phase after a single leg drop jump (DJ) landing on a force plate may serve as a proxy for a single leg stance (SLS) balance task. Twenty-five healthy participants performed two sessions of five valid trials for both tasks in a reproducibility-agreement design. Bland and Altman methods demonstrated inter-session SD's of difference for DJ of 11-12% and for SLS of 10-12%, while inter-task SD's of difference ranged 10-17%. Therefore, a DJ task may be used as a proxy for static postural stability. The incorporation of static postural stability into the DJ test could enhance large-scale measurement programs, such as the periodic testing programs in (professional) football, by providing information on both the dynamic aspect (e.g., landing forces, time to stabilization) and the static aspect (postural stability) of sensorimotor functioning.

In **chapter 4**, we determined the existence of possible distinct phases of a single leg drop jump landing on a force plate. Three outcome measures were calculated over moving windows: center of pressure (COP) speed, COP sway, and horizontal ground reaction force (GRF). Per outcome measure, a Factor Analysis was employed with all windows as input variables. It showed that four factors (patterns of variance) largely (>75%) explained the variance across subjects/trials along the 12 s time series. Each factor was highly associated with a distinct phase of the time series signal: dynamic (0.4-2.7 s), late dynamic (2.5-5.0 s), static 1 (5.0-8.3 s), and static 2 (8.1-11.7 s). Therefore, following a drop jump landing unique information is available in four distinct phases. Future studies should assess the sensitivity of information from dynamic, late dynamic, and static phases.

In **chapter 5**, we explored the outcome measure time to stabilization (TTS). The TTS is the time it takes for an individual to return to a baseline or stable state following a jump or hop landing. A large variety exists in methods to calculate the TTS. These methods can be described based on four aspects:

1. the input signal used (vertical (V), anteroposterior (AP), or mediolateral (ML) ground reaction force)
2. signal processing (smoothed by sequential averaging, a moving root-mean-square window, or fitting an unbounded third order polynomial)
3. the stable state (threshold)
4. the definition of when the (processed) signal is considered stable

We calculated the TTS according to 18 previously reported methods. Additionally, we assessed the effects of sample rate, filter settings, and trial length. The TTS values varied considerably across the calculation methods. The effects of differences in sample rate and filter settings are generally small, while trial length had a large effect on TTS values.

In **chapter 6**, we aimed to provide insight in how threshold selection affects TTS and its reliability. The TTS was calculated based on four processed signals: raw ground reaction force (GRF) signal (RAW), moving root mean square window (RMS), sequential average (SA), or unbounded third order polynomial fit (TOP). For each trial and processing method a wide range of thresholds was applied. Per threshold, reliability of the TTS was assessed through intra-class correlation coefficients (ICC) for the V, AP, and ML direction of force. The TTS and ICC were mostly 'insufficient' (<0.4) to 'fair' (0.4-0.6) for the entire range of thresholds for RAW and RMS. The SA signals resulted in the most stable ICC values across thresholds, being 'substantial' (>0.8) for V, and 'moderate' (0.6-0.8) for AP and ML direction. The ICC's for TOP were 'substantial' for V, 'moderate' for AP, and 'fair' for ML direction. Irrespective of threshold selection, the SA and TOP methods yielded sufficiently reliable TTS values, while for RAW and RMS the reliability was insufficient.

In **chapter 7**, we assessed the relation between TTS and dynamic postural stability index (DPSI), the relation of both measures with impact forces and dynamic postural sway, and how they related to static postural sway. The different TTS measures were significantly interrelated ($r=0.28-0.53$), but were not significantly correlated to DPSI. The TTS was more strongly related to horizontal GRF (0.4-2.4 s) ($r=0.54-0.75$) than to horizontal GRF (3.0-5.0 s) ($r=0.32-0.54$) or impact forces ($r=-0.28-0.36$). Vertical TTS was not significantly related to impact forces. The DPSI was most strongly related to the vertical peak force ($r=0.85$), and was not significantly related to horizontal GRF of the dynamic periods. Furthermore, TTS and dynamic horizontal GRF were significantly related to static horizontal GRF ($r=0.34-0.80$), while DPSI and impact forces were not. Therefore, TTS and DPSI do not represent similar aspects of single leg jump landing performance. The ability

to stabilize posture seems to be represented by TTS and dynamic postural sway, which partly overlaps with static postural sway. In contrast, DPSI and vertical peak force mainly reflect the kinetic energy absorption during impact.

In **chapter 8**, we assessed the relation of drop jump landing performance and the risk of lateral ankle sprains within three years follow-up in a group of 190 elite footballers. Based on ground reaction forces, six outcome measures were calculated that aim to reflect the impact and stabilization phase. Following a z-score correction for age, a multivariate regression analysis was performed.

During follow-up, 45 players (23.7%) suffered from a primary lateral ankle sprain. Of those, we regarded 34 as severe (>7 days absence). Performance was related to increased risk of ankle sprain ($p=0.005$ for all sprains, and $p=0.001$ for severe sprains). Low mediolateral stability for the first 0.4 s after landing (a larger value indicates more force exerted in mediolateral direction, resulting in rapid lateral stabilization) and a high horizontal ground reaction force between 3.0-5.0 s (a smaller value indicates less sway in the stabilization phase) were identified as risk factors. A player that scored 2 SD below average for both risk factors had a 4.4 times higher chance of sustaining an ankle sprain than a player who scored average.

Finally, in **chapter 9**, we reflect on the main findings of this thesis, as well on the limitations of the studies and injury screening in general. We provide practical implications and advice for future research.

A comprehensive understanding of employed outcome measures before making any conclusions or decisions is very important. Based on a dynamic test and relevant outcome measures, we have shown a relation between performance and injury risk. To take the next step in injury prevention, clubs (or associations) need to start cooperating, reach consensus about what to measure, and have a collaborative institute responsible for data management and analysis. Perhaps then we will be able to use screening tests to identify the athletes at risk for a sports injury – in order to address the deficit through a targeted intervention programme.