

Mind your step

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Summary

This thesis aimed to gain insight into the role of hip abductor muscle strength in fall risk in older adults and assess its ability to discriminate between older fallers and non-fallers. We were interested in the possible potential of hip abductor strength as a fall-risk assessment either in single use or within a test battery.

The **Peface** gives an introduction in a scenario that we all lived and makes us realize the importance of falls and their associated deleterious consequences. The preface allows an emotional entry into research, which underlines that the present project is not just « one more of those projects about fall risk assessments...». The preface makes us realize how much this subject can touch us personally and how much we are emotionally linked to it.

- What would you like to know to support your loved ones in preventing a fall?
- Which questions would you like to have answered in relation to fall risk?
 - *fWhich factors influence falls?*
 - *What tests can evaluate those fall-influencing factors?*
 - *What does science say regarding fall risk and fall-risk assessments?*

Chapter 1 introduces the importance of the theme of fall risk by underlying the demographic changes that are leading to a drastically increasing number of older people, which implicates an associated increasing fall incidence. Many factors influence the construct “fall risk”. However, the focus of this dissertation is on the physiological factors, the parameters that are modifiable and important for guiding the content of a physical therapy intervention, such as decreased balance, strength, and mobility. Chapter 1 further discusses the necessary aspects we need to understand such as falls and fall-influencing factors, what kind of test do exist for evaluating those fall-influencing factors, the influence of lower limb muscle strength and more specifically the reasoning of the interest in hip abductor strength in relation to fall risk. As such, Chapter 1 gives information about the important parameters for the choice of a test for fall-risk assessment and the taxonomy, definitions, and methodological aspects of clinimetric studies. In fact, functional lower-extremity weakness in older persons is a strong indicator that could enhance the unfortunate transition from a non-faller into a faller, and its assessment and treatment for persons at risk of falls is recommended. Recent literature underlines the significance of hip abductor muscle strength to maintain mediolateral balance control, a factor that is often reduced in older persons, especially fallers. Hip frontal plane muscle strength and spinal moments of force are the dominant muscles to counteract destabilization in the mediolateral direction during single leg support and showed a more pronounced decline in strength compared to muscles acting in the sagittal plane. The mentioned facts led to the hypothesis that hip abductor strength could be a promising contributing factor for assessing fall risk. Because this approach seemed to be clinically relevant and novel, we decided to

investigate the hip abductor muscle group in greater detail. We planned to establish cut-off values and diagnostic accuracy to facilitate the clinical decision-making process regarding older individuals' fall risks. The validation of this approach provides clinicians not only an additional fall-risk assessment to the already existing test battery but might also give crucial information about a directly targetable parameter for fall prevention.

With this dissertation, we addressed two main issues, which are divided in Part 1 and Part 2.

Part 1: The role of hip abductor strength in the field of fall-risk assessment and development of a new measurement instrument and procedure for daily clinical use

The first part of this dissertation (Chapters 2 to 6) concentrated on the role of hip abductor strength in the assessment of fall risk of persons 65 years and over. It was planned to assess feasibility, reliability, and validity of our measurement method for hip frontal plane strength assessments. In a later emerging project, we further develop a hip abductor strength test to obtain a new and functional testing procedure that is easy to use.

Within **Chapters 2 and 3**, the feasibility and intra-rater reliability of the hip frontal plane strength assessment in side-lying position and the hip abductor strength assessment in a standing position were assessed. Relative and absolute reliability are a prerequisite for good validity. In **Chapter 2** we used a standardized way to measure hip abductor and adductor strength in which the participant was in a side-lying position and pushed his or her leg as hard and fast as possible against a dynamometer fixed to a custom-made, metallic frame that was fixed to the treatment table. Seventy-six participants aged 65 years and over were recruited from a geriatric hospital that is part of the Geneva University Hospitals and in an outpatient practice in Switzerland. Thirty-eight persons underwent the abduction and the other 38 persons the adduction test. The participants were tested twice within one to three hours by the same rater. Intraclass correlation coefficient ($ICC_{\text{agreement}}$), standard error of measurement (SEM), and smallest detectable difference (SDD) were determined and showed that hip abductor and adductor maximum voluntary isometric strength (MVIS) and rate of force generation (RFG) assessment in side-lying position is feasible and shows high values for reliability in persons 65 and older. However, the assessment time of around 10min in side-lying position is too long for daily clinical use.

This led to the assessment of the feasibility and reliability of the hip abductor strength assessment in a standing position in **Chapter 3**. As for Chapter 2 individuals over 65 years of age were recruited from the geriatric department of a university hospital and an outpatient clinic. Thirty-two older subjects, including 16 fallers (≥ 1 fall during the last 12 months) and 16 non-fallers were included. MVIS and RFG of the hip abductors of the right leg were evaluated in a standing position using a hand-held dynamometer. Two test-sessions were carried out by

the same rater one to three hours apart. Reliability was determined using the $ICC_{\text{agreement}}$, the SEM and a Bland and Altman analysis. The results showed that hip abductor strength assessment in a standing position is feasible and achieves $ICC_{\text{agreement}}$ values that are as high as the ones assessed in a side-lying position. The advantage of the test in standing position is that it takes about half the time the hip abductor strength assessment takes in a side-lying position and hence seems much more feasible in clinical practice. Although both testing positions showed a good intra-rater reliability, in both cases, high SEM and SDD were evaluated, with values of SDD that are slightly lower in the standing than in the side-lying position.

To be able to answer the question about the importance of hip abductor strength in relation to fall risk, we evaluated in **Chapter 4** which of the six hip muscle groups best discriminates between older fallers and non-fallers and compared their discriminative ability with the one of the handgrip strengths. In 60 older persons aged 65 years and over (38 females, 22 males) the MVIS and RFG of hip abductors, adductors, internal and external rotators, extensors and flexors were measured with a dynamometer fixed to a custom-made frame as well as handgrip strength with a Martin Vigorimeter. It turned out that hip abductor strength was the only assessed hip muscle strength group that showed a discriminative ability that was predefined as good enough for clinical use ($AUC > 0.7$), as compared to the chosen reference standard fall history. Therefore, the results of Chapter 4 indicate that hip abductor MVIS is a useful measure to distinguish between older adult fallers and non-fallers regarding the chosen external criterion.

This led us to continue with the evaluation of the specific psychometric properties of the hip abductor strength in **Chapter 5**. Chapter 5 is an extended evaluation and a next step to the results of Chapter 4. The diagnostic accuracy of hip abductor muscle strength was examined to decide whether this parameter should be integrated in a test battery to assess older persons' fall risks. Thus, we also calculated net sensitivity and specificity to get insight in its possible combination with our chosen fall risk assessments, short physical performance battery (SPPB) and Timed up and Go (TUG) test. All of the 60 included patients' demographic data (e.g. age, sex, and BMI) were extracted from the clinical database, the reference standard fall history was collected by verbal questioning and thereafter, trained physical therapists (blinded to the participants' fall histories) assessed the Falls Efficacy Scale International, Mini Mental State Examination, the SPPB and TUG, as well as participants' hip abductor strength (MVIS and RFG). The results of Chapter 5 indicate that hip abductor strength (MVIS and RFG) shows good diagnostic accuracy to differentiate between older fallers and non-fallers. The high net sensitivity when hip ABD strength measurements (MVIS and RFG) are combined with currently used fall risk assessments shows its promising contributing value to a test battery. Hip abductor

strength is an easily measurable parameter and should, on a daily clinically basis, be considered as an important influencing factor of fall risk.

However, during the different projects of Chapters 2 to 5, we were confronted with more challenges in relation to the assessment position as well as the measurement instrument for hip abductor strength assessment and its functional and mostly clinical applicability throughout the mentioned studies. This led us to reflect, and inspired a way to assess hip abductor strength in daily clinical life. Therefore, with the focus on allowing our previous findings to be integrated in clinical practice, the additional project for the development of a measurement procedure in standing position emerged for this thesis and is addressed **in Chapter 6**. With the assistance of engineers of the Institute of Industrial Technologies and Sciences, University of Applied Sciences and Arts Western Switzerland (HES-SO Geneva/HEPIA), a prototype of an easy to manipulate and transportable measurement instrument and associated measurement procedure was developed and a patent was filed in October 2020 (impact paragraph). Consequently, with the goal of evaluating the adapted measurement procedure to allow a later use in daily clinical life, the study protocol of a reliability and validity study with the adapted measurement instrument and procedure was developed and is elaborated in Chapter 6.

Part 2: The diagnostic accuracy of currently used fall-risk assessments (including strength measures) to gain insight into their ability for fall risk detection and/or prediction

Chapter 7 assessed in a systematic review the clinimetric properties of other tests that assess body functions and structures and/or the ICF “activities and participation” components in relation to fall risk of older persons. Aware of the multifactorial etiology of falls and assuming that hip abductor strength will have to be combined with other performance-based fall risk assessments for a good fall risk detection, we aimed to provide an overview of the reliability (inter- and intra-rater) and diagnostic accuracy, specifically post-test probability, of commonly used performance tests to assess the fall risk of persons 65 years and older, according to their setting (community dwelling, nursing home, or hospital). The goal was that this overview can support caregivers in making decisions with the person at risk of falls to help them choose a suitable fall-risk assessment corresponding to the patient’s specific setting.

Overall, 42 articles were retained for the systematic review of which 21 articles contained information of reliability and 25 of validity. Four of the included articles contained information for reliability and validity of the included test. To facilitate the clinical applicability and because the diagnostic accuracy of tests is strongly influenced by the population under study, we summarized our findings according to the settings of the results (community-dwelling, nursing home, hospital, and combined setting of hospitalized and community-dwelling persons). In

general, the systematic review showed that the discriminative ability of the included tests to detect persons at risk of falling is not very good for clinical use. Most of the included tests only show relatively low sensitivity values and small changes from pre- to post-test probabilities. Thus, our results as well as the knowledge of the multifactorial etiology of falls underline that the currently used fall risk assessments are in a single-use not good enough to discriminate between older fallers and non-fallers. To be able to choose an appropriate fall risk assessment health care professionals should know and understand the clinimetric properties of a test. In our systematic review, we explain important aspects of a measurement instrument, their influencing factors and their interpretation for clinicians. A clinical application of its results in everyday practice can easily be done and supports the decision-making process between patient and caregiver.

Chapter 8 and Chapter 9 are completing this thesis with a general discussion and the impact paragraph. **Chapter 8** discusses our main findings, presents reflections on strength, limitations and methodological aspects of our studies, and provides implications for clinical practice and future research. Assessing hip abductor strength helps with understanding older persons' fall risks. The hip-abductor-strength assessment is feasible in older persons, shows good clinimetric properties and provides additional value to currently used fall risk evaluations and, thus, to fall risk prevention and rehabilitation programs. It evaluates complementary aspects of falls but is not yet measured systematically. Furthermore, currently used performance-based fall-risk assessments only show moderate ability to discriminate between fallers and non-fallers, and the setting where the tests will be performed strongly influences which tests can be recommended for clinical use. The clinical applicability of the findings is highlighted in Chapter 8. Importance is given to the fact that researchers must make their work understandable for direct application to clinical life and that closing the gap between research and practice to develop best-practice guidelines for patients is required.

Finally, **Chapter 9** reflects on the scientific and societal significance of my research projects and, most importantly, the significance of the results at the patient level. The present research aimed to enhance clinical work and improving patients' outcomes by identifying relevant parameters for the future development of a targeted therapy for fall risk. The knowledge gained from the different projects comprising this PhD thesis are beneficial for researchers, healthcare professionals, persons aged ≥ 65 years, and relatives of people who are at risk of falls. Therefore, it has high scientific, societal and clinical impacts. We recommend assessing hip abductor strength for diagnostic purposes and encourage its assessment in daily clinical use.