# Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

***Masterthesis***

***Possible predictors for higher risk of falling in healthy older adults, based on multidimensional testing***

**Siebe Meekers**

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen

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# Table of Contents

# Contextualization

This master's thesis was conducted as part of the subject In-depth Scientific Internship and Master's Thesis within the educational program Rehabilitation Sciences and Physiotherapy at Hasselt University, academic year 2024-2025. The research is situated within the field of Technology-supported Rehabilitation and within the project 'From Steps to Context: Optimizing Digital Phenotyping for Physical Activity Monitoring in Older Adults by Integrating Wearable Data and Ecological Momentary Assessment.' This project was in collaboration with Kim Daniels, and her colleagues of Centre of Expertise in Care Innovation, Department of Healthcare, PXL University of Applied Sciences and Arts, Hasselt and is registered under Clinical Trials Identifier (NCT06094374) and has been ethically approved by the Ethics Committee of Hasselt University (B1152023000011).

Falling represents a serious and common health issue among older adults. The risk of falling increases as people age, due to multidimensional factors. A fall can result not only in physical injuries but also in loss of independence, fear of falling, and a reduced quality of life. Over the last few years people are getting older and therefore live longer. Because of this there is a growing urgency to develop effective prevention and intervention strategies. It is important to understand and identify risk factors of falling among older adults.

This master's thesis is a trio research project, in which all three students collaborated on all parts of the research process. The subject of the research was a shared decision and consulted with Bruno Bonnechère, the promotor. All three students contributed to the writing and analysis of this thesis evenly. Except for the statistical analysis, this part was mostly executed by Siebe Meekers. During the research there was a constant interaction between the students with the joint coordination of writing and processing data and feedback.

The aim of this research is to contribute to better understanding and identification of risk factors of falling among older adults to support the development of prevention and tailored interventions for older adults with a higher risk of falling.

# Abstract

**Background:** Falls in older adults are a major public health concern considering the increasing number of aging older adults. Falls are associated with significant consequences, including physical injuries and loss of independence. Identifying risk factors is therefore crucial in fall prevention and developing tailored interventions.

**Objectives:** The study aimed to identify possible predictors for an increased risk of falling in healthy older adults, based on multidimensional testing.

**Method:** A cross-sectional study was conducted including 73 healthy older adults, aged 65 and older. Baseline measurements consisted of Six-Minute Walking Test, Timed Up and Go, quadriceps strength, handgrip strength, age, and reaction time. Fall incidents were tracked over a six-month period through a questionnaire. Participants were categorized as fallers (n = 10) or non-fallers (n = 63).

**Results:** Univariate analyses showed a statistically significant difference in Reaction Time between the fallers and non-fallers ($p = 0.006$). The final logistic regression model included the parameters Age, Reaction Time, Handgrip Strength and the interaction between Age and Reaction Time. The model demonstrated acceptable fit based on the whole model test and the Akaike Information Criterion corrected ($p = 0.013$, AICc = 56.542) as well as a good theoretical discriminative ability (AUC = .805). However, practical application showed poor sensitivity (20%) but high specificity (98.4%).

**Conclusion:** Reaction time may serve as a simple and efficient screening tool to assess fall risk in older adults. However, more research is needed to evaluate other risk factors and to have a better understanding of its impact on prevention strategies.



**Key words:** older adults, risk of falling, reaction time

# Introduction

Each second, a senior citizen takes a fall somewhere around the globe. Every 11 seconds, such a fall results in a visit to the emergency room. Globally, 66% more people die from falls each year than from malaria—highlighting the often-underestimated impact of falls, especially among older adults (Expertisecentrum Val- en fractuurpreventie Vlaanderen, n.d.). According to the World Health Organization (WHO), 28-35% of people aged 65 and older experience at least one fall each year worldwide. As people are living longer and the proportion of those aged 65 and older continues to grow rapidly, this trend poses a significant challenge to healthcare systems across the globe. This makes falling one of the most prevalent and serious health risks in older adults, with the risk increasing with age (World Health Organisation, 2021b).

Even though falling is often seen as a consequence of aging, its consequences should not be underestimated, as it can lead to both physical injuries and lasting psychological effects. Dislocations, broken bones, head traumas, skin wounds, and long-lasting disabilities are prevalent physical injuries (Rubenstein, 2006). Beyond the physical consequences, psychological consequences are also related to a fall. For example, fear of falling can lead to reduced physical activity, mobility, ultimately leading to social isolation (Delbaere et al., 2012). Other examples include, but are not limited to, anxiety, decreased self-confidence and self-efficacy, increased dependency, and a reduced quality of life (Delbaere et al., 2010; Luuc, 2023).

The impact of falls extends beyond the individual, affecting society as well. In 2019-2020, 31% of the fallers were hospitalized, which led to rising healthcare costs. (Moreels et al., 2024). In older patients who are hospitalized with an acute illness, a fall might not only lead to a longer hospitalization but is significantly associated with an increased likelihood of admission to a nursing home. This transition also contributes to higher healthcare costs (Basic & Hartwell, 2015).

Predicting the risk of falls in older adults at an early stage is a crucial step toward the development and implementation of personalized prevention interventions. Programs such as balance and strength training have proven to be effective in decreasing the number of falls but also, and more importantly, the severity of the consequences of these falls (e.g. fall-related fractures and other falls requiring medical attention). These fall-outcomes are considered the main reason for an increase in healthcare costs (Sherrington et al., 2019).

To accurately assess the risk of falls, it is essential to consider multiple contributing factors. Risk factors contributing to increased risk of falls have previously been identified such as orthostatic hypotension, polypharmacy, poor balance, reduced force (i.e., due to sarcopenia), gait or mobility disorders, cognitive disorders, reduced vision, low vitamin D, pain, urinary incontinence or an unsafe environment (carpets, insufficient lighting, etc.) (Gezondheid en wetenschap, 2022). Furthermore, comorbidities such as stroke, dementia, Parkinson's, cardiovascular and respiratory disease, peripheral neuropathy, diabetes, chronic pain, arthritis, osteoporosis, etc., are also associated with an increased risk of falls (Bailey, 2023).

To this day, the Timed Up and Go (TUG) test and the Berg Balance Scale (BBS) are widely used to assess the risk of falls. While these tests demonstrate strong validity and specificity and apply to a broad range of balance-related issues, they often provide a limited perspective, as they primarily focus on balance and mobility (Berg et al., 1992).

Research has shown that falling does not occur solely from physical limitations, but also from a combination of physical, cognitive, and environmental factor. Multidimensional testing offers a more comprehensive approach to evaluating the risk of falls, in which multiple components can be analysed (Muir et al., 2010).

To be able to identify the relationships between these different risk factors for falls, it is therefore of the utmost importance to develop a multifactorial approach to establish a specific risk profile. By taking the physiological, cognitive, and behavioural contributors to risk of falls into account, this approach will allow tailored interventions that maximize fall prevention effectiveness (Delbaere et al., 2010).

Even though more attention is being paid to combining multiple measuring methods, there are still significant gaps in the current literature. Many studies aim at performing and studying single dimensions, such as balance, cognition, speed, or muscle power, while the interactions between these components are still insufficiently examined (Ambrose et al., 2013). Furthermore, there is little consensus on which combinations of testing seem to be the most effective in predicting the risk of falls. This lack of knowledge limits the development of evidence-based screening methods and interventions.

Therefore, this study aimed to develop a highly multidimensional assessment tool to evaluate the risk of falls in healthy older adults to determine which parameters are the most predictive.

# Method

## *Study design*

This study was part of a larger project conducted by the Centre of Expertise in Care Innovation, Department of Healthcare, PXL University of Applied Sciences and Arts, Hasselt. This project aimed to investigate the level of physical activity, participation, and lifestyle in healthy older adults. The study was approved by the Ethics Committee of Hasselt University (B1152023000011), and all participants provided written informed consent before participating. Data was processed anonymously.

For this specific study, certain data from the study named above was extracted. A cross-sectional study has been conducted, consisting of two assessment points. The first assessment included multidimensional testing (fully described below) while the second assessment point, conducted six months later, investigated episodes of falling over the past six months. Participants were then classified into two groups: fallers (people who have reported at least one fall in the past six months) and non-fallers (people who have not reported a fall during the same period).

## *Participants*

Participants were recruited through newspaper and radio advertisements, social media, presentations at senior citizen organisations, and collaboration with local community services.

Inclusion criteria were age above 65 years old, competent to give informed consent, physically able to participate, community-dwelling (living independently at home or in a service apartment), no severe illnesses impairing mobility, functional capacity, or cognitive ability to the extent that they could not comprehend or follow instructions, and they had to be native Dutch speakers.

Exclusion criteria included current neurological disorders, defined as diseases that affect the central and peripheral nervous system (Cleveland Clinic, 2024); cardiovascular diseases, which refer to a group of disorders involving the heart and blood vessels (World Health Organisation, 2021a); respiratory disorders, defined as diseases that impair lung function and affect the airways and other structures of the respiratory system (World Health Organisation, n.d.); severe cognitive disorders, which fall under the broader category of mental disorders and are characterized by clinically significant disturbances in cognition, emotional regulation, or behaviour (World Health Organisation, 2022) and severe metabolic disorders, referring to a spectrum of metabolic dysregulation processes affecting obesity-linked insulin resistance, glucose homeostasis, lipid metabolism, pro-inflammatory immune cells, and cytokines (Chew et al., 2023).

## *Materials and methods*

For the first part of this study several technologies were used to measure multiple outcomes such as handgrip strength, quadriceps strength, balance, reaction time, Timed Up and Go (TUG) and 6-Minute Walk Test (6MWT), which are all relevant to fall risk in older adults.

The Kinvent®2016 (Kinvent, Montpellier, France) system was used to assess the participants' quadriceps strength, handgrip strength, and balance. This system included an app that connects to various devices, enabling objective measurement of physical performance. For this study, the K-Force plates, K-Push, and K-Grip devices were used.

To assess the quadriceps strength, the K-push (hand-held dynamometer) was used. The isometric strength was measured using this device. Participants had to sit on the edge of a Bobath table with their feet off the ground and had to push their leg into the device. The researcher was holding the device against the participant's shin. Participants had to perform this test for five seconds, three times on each leg.

Static balance was assessed using the K-force plates. The device measured the amount of sway a participant has during a 15-second stance. Bipodal stance was assessed three times, both with eyes open and eyes closed. Unipodal stance was assessed three times for each leg with eyes open. The validity and reliability of the K-force plates have been compared to gold standard balance assessments (Meras Serrano et al., 2023).

The handgrip strength was measured using the K-grip device. This device measured the isometric strength of the hand. It is similar to the Jamar and has an excellent intra-rater reliability (ICC = 0.96-0.97) (Magni et al., 2023; Nikodelis et al., 2021). The participants were seated with their elbow flexed at 90 degrees and their hand in a neutral position. They had to squeeze the device for five seconds, three times for each hand.

Furthermore, the reaction time was assessed using the Sway Medical app, which includes two different tests. The first test assessed reaction time, and the second test evaluated impulse control. Sway Medical compared the participants' results to a reference group—based on age and other personal characteristics—to calculate a percentile score.

In addition, the TUG and 6MWT were performed to assess functional mobility and endurance, aerobic capacity, as well as balance and fall risk.

For the TUG, participants had to stand up from a chair, walk three meters, turn around, walk back, and sit down. A time higher than 13.5 seconds indicated an increased fall risk.

For the 6MWT, participants were instructed to walk as far as possible in six minutes. The total distance covered was recorded, as well as the BORG Rate of Perceived Exertion (BORG RPE) scale before and after the assessment.

Both the TUG (Christopher et al., 2021) and 6MWT (Arcuri et al., 2016) are valid and reliable.

For the second part of this study a follow-up questionnaire was administered after six-months to evaluate whether participants had experienced a fall within the previous six months. Based on their responses, participants were categorized into two groups: fallers and non-fallers.

### *Data analysis*

All statistical analyses were performed using JMP Pro Version 17 (SAS Institute Inc., Cary, NC, USA). In the study, whether a participant had experienced a fall in the past 6 months was chosen as the dependent variable. Given that this variable "fallen" only has 2 levels (1 = yes, 2 = no), it was encoded as a binary categorical variable. The remaining variables, all consisting of continuous measurements, were chosen as independent variables, namely: age, Timed Up and Go (TUG), the Six-Minute Walking Test (6MWT), reaction time, quadriceps strength of the dominant side, and hand grip strength of the dominant side.

Although the measurements for the age and TUG variables are the absolute values as measured during the study, reference values were used for the 6MWT, reaction time, quadriceps strength and hand grip strength. These were calculated by comparing each participant's absolute score with the expected norm value for persons of the same sex, age, and height, resulting in a score expressed as a percentage of the reference value.

The first step of this data analysis was six different univariate analyses, in which the individual parameters were compared separately between the group of fallers (n = 10) and the group of non-fallers (n = 63). Since we are dealing with continuous data from two independent groups, of which one group contains less than 30 subjects (fallers: n = 10), the normality of the data was first checked within both groups for each individual variable. This was done by setting up the QQ plots and objectively evaluating the normality based on the Shapiro-Wilk test. Next, homoscedasticity, equal variances within both groups, had to be checked using the Brown-Forsythe test. If the data of at least one of the two groups was not normally distributed but the variances were considered the same for both groups, the non-parametric Wilcoxon rank-sum test was used. In the case of normally distributed data for both groups with equal variances, a 2-sample t-test was used to calculate the p-values.

After these exploratory univariate analyses of the data, a multiple logistic regression analysis was performed. The dependent response variable "fallen" was predicted based on the independent continuous variables mentioned above. For the initial model, all main effects as well as their interaction with age were included.

This comprehensive model was simplified using backward stepwise model selection based on the p-values from the likelihood ratio tests for these individual variables and interactions. This way, non-significant predictors and interactions were gradually removed from the initial model, to arrive at a model that had the lowest possible AICc (Akaike Information Criterion corrected). The corrected version was chosen because of the small population (n = 73), to avoid overfitting and unnecessary complexity.

After applying model building, the final model consisted of the following remaining factors: Age, Reaction Time, Handgrip Strength, and the interaction Age*Reaction Time.

Finally, multiple statistical procedures were performed to evaluate the predictive capabilities of the model. The overall model fit of the final model was assessed using the whole model test, as well as the AICc mentioned above, to determine the optimal balance between model complexity and goodness-of-fit. To assess for potential multicollinearity between the independent parameters, the Variance Inflation Factor (VIF) was calculated using the determination coefficient ($R^2$). To finish, the model's theoretical ability to distinguish between fallers and non-fallers was analysed by performing a Receiver Operating Characteristic (ROC) analysis.

# Results

## *Univariate Analyses*

**Table 1**

*Group Differences Between Fallers and Non-Fallers on Individual Predictor Variables*

| Parameter | Test used | Fallers (n = 10) | Non-Fallers (n = 63) | P-value | Interpretation |
|---|---|---|---|---|---|
| Age (years) | Wilcoxon rank-sum test | m = 70.50<br>IQR = 6.75 | m = 68.00<br>IQR = 4.00 | .392 | No significant difference between Fallers & Non-Fallers |
| TUG (seconds) | Wilcoxon rank-sum test | m = 5.66<br>IQR = 1.10 | m = 5.97<br>IQR = 1.44 | .356 | No significant difference between Fallers & Non-Fallers |
| 6MWT (% predicted) | Wilcoxon rank-sum test | m = 117.50<br>IQR = 19.50 | m = 120.00<br>IQR = 25.00 | .930 | No significant difference between Fallers & Non-Fallers |
| Reaction Time (% predicted) | Wilcoxon rank-sum test | m = 93.00<br>IQR = 16.75 | m = 77.00<br>IQR = 22.00 | .006 | Significant difference between Fallers & Non-Fallers |
| Quadriceps Strength (% predicted) | 2-sample t-test | M = 125.70<br>SD = 9.36 | M = 116.43<br>SD = 3.73 | .180 | No significant difference between Fallers & Non-Fallers |
| Handgrip Strength (% predicted) | 2-sample t-test | M = 97.00<br>SD = 5.13 | M = 88.33<br>SD = 2.04 | .060 | No significant difference between Fallers & Non-Fallers |

*Note. TUG = Timed Up and Go; 6MWT = Six-Minute Walking Test; M = mean; m = median; IQR = interquartile range (Q3-Q1); SD = Standard Deviation; Percentages indicate the score compared to the expected standard values*

### Age

First, the normality of the data was checked using QQ plots and the Shapiro-Wilk tests. The data of the variable age was normally distributed in the group of fallers ($p$ = .818; α = 0.05), but not normally distributed in the group of non-fallers ($p$ < .0001; α = 0.05). Thus, the variances between both groups were evaluated using the Brown-Forsythe test. The variances were evenly distributed ($p$ = .937; α = 0.05). Based on these results, the Wilcoxon Rank-Sum test was chosen ($p$ = .392; α = 0.05). This value does not indicate significant differences in age between the two groups.

### Timed Up and Go (TUG)

The data of the variable TUG was normally distributed in the group of fallers ($p$ = .891; α = 0.05), but not normally distributed in the group of non-fallers ($p$ = .018; α = 0.05). The variances were evenly distributed ($p$ = .419; α = 0.05). Based on these results, the Wilcoxon Rank-Sum test was chosen ($p$ = .356; α = 0.05). This value does not indicate significant differences in TUG between the two groups.

### Six-Minute Walking Test (6MWT)

The data of the variable 6MWT was not normally distributed in the group of fallers ($p$ = .002; α = 0.05) but was normally distributed in the group of non-fallers ($p$ = .370; α = 0.05). The variances were equally distributed ($p$ = .611; α = 0.05). Based on these results, the Wilcoxon Rank-Sum Test was chosen ($p$ = .930; α = 0.05). This value does not indicate significant differences in 6MWT between the two groups.

### Reaction Time

The data for the variable Reaction Time was not normally distributed in both groups (fallers: $p$ = .027; α = 0.05 and non-fallers: $p < .0001$; α = 0.05). The variances were evenly distributed ($p$ = .271; α = 0.05). Based on these results, the Wilcoxon Rank-Sum Test was chosen ($p$ = .006; α = 0.05). This value indicates significant differences in Reaction Time between the two groups. The fallers had a significantly slower Reaction Time than the non-fallers.

### Quadriceps Strength

The data of the variable Quadriceps Strength was normally distributed in the group of fallers ($p$ = .482; α = 0.05), and in the group of non-fallers ($p$ = .211; α = 0.05). The variances were evenly distributed ($p$ = .678; α = 0.05). Based on these results, the 2-sample t-test ($p$ = .180; α = 0.05) was chosen. This value indicates no significant difference in Quadriceps Strength between the two groups.

### Handgrip Strength

The variable Handgrip Strength was normally distributed in the group of fallers ($p$ = .319; α = 0.05), and in the group of non-fallers ($p$ = .348; α = 0.05). The variances were equally distributed ($p$ = .058; α = 0.05). Based on these results, the 2-sample t-test ($p$ = .060; α = 0.05) was chosen. This value indicates no significant difference in Handgrip Strength between the two groups, although it approaches the threshold of 0.05.

### *Multiple Logistic Regression*

**Table 2**

*Parameter Estimates for the Final Logistic Regression Model Predicting Fall Risk*

| Parameter | Estimated value |
|---|---|
| Intercept | 134.793528 |
| $\beta_1$ | -2.1472355 |
| $\beta_2$ | -1.5404071 |
| $\beta_3$ | .03902524 |
| $\beta_4$ | .02359935 |

**Table 3**

*Cut-off Values and P-Values for Predictors in the Final Model*

| Parameters | P-value | Cut-off score |
|---|---|---|
| Age | .068 | 69.97 |
| Reaction Time | .081 | 75.86 |
| Handgrip Strength | .099 | 89.52 |
| Age*Reaction Time | .065 | / |

After using backward stepwise model selection, a final model consisting of four terms remained: Age ($p$ = .068), Reaction Time ($p$ = .081), Handgrip Strength ($p$ = .099), and the interaction Age*Reaction Time ($p$ = .065). Although these p-values are all above the conventional threshold of .05, they were still considered relevant in the context of overall model performance and stability.

The factor Handgrip Strength was not statistically significant on its own, but it was included in the final model because its exclusion resulted in the loss of statistical significance of the remaining factors. This drop in significance became especially clear after removing the variable Quadriceps Strength, which also caused the p-values of the other predictors to increase. Based on this pattern, there might be potential multicollinearity between the different predictors. However, the Variance Inflation Factor (VIF) indicated a value of 1.05, which is well below the commonly accepted threshold of 10 and therefore does not indicate any reason for problematic multicollinearity.

Table 3 shows the p-values for the parameters included in the model, as well as their corresponding cut-off values that were derived from the ROC analysis to optimize the model's sensitivity and specificity: 69.973 years for Age, 75.863% for Reaction Time and 89.521% for Handgrip Strength.

The whole model test indicated that the model was sufficiently significant ($p$ = .013), having the smallest p-value of all the models evaluated it performs significantly better than these models or a null model. The model had an AICc of 56.542, the lowest value of all tested models which indicates the best overall model fit.

The predictive capacity of the final model was analysed using a ROC curve. This resulted in an Area Under the Curve (AUC) of .805, which means that the model can theoretically distinguish between fallers and non-fallers. With the chosen classification thresholds, the model has a sensitivity of 100% and a specificity of 52.38%, indicating a strong ability to detect fallers with a moderate ability to correctly detect non-fallers.

However, when looking at the confusion matrix (Appendix A – Table A) it shows a discrepancy between the theoretical and practical performance of the model. The model was able to only correctly identify two out of the ten actual fallers, despite the high theoretical sensitivity. The eight remaining true fallers were incorrectly classified as non-fallers, indicating only two true positives and eight false negatives. One non-faller was incorrectly classified as a faller, resulting in one false positive. Based on these findings the model displays a practical sensitivity of 20% and specificity of 98.4%, instead of the theoretical sensitivity of 100% and specificity of 52.38%. This confusion matrix shows that the model's classification threshold is imbalanced, resulting in misleading performance metrics that do not translate into effective real-world predictions.

## Discussion

This study offers valuable scientific insights into the prediction of fall risk in healthy older adults through a multidimensional testing approach. The aim was to identify potential predictors associated with an increased risk of falling. Although the initial hypothesis assumed significant differences between fallers and non-fallers across different domains (functional, physical, and cognitive), only limited significant associations were found — most notably in reaction time.

Nevertheless, the findings highlight the potential of multidimensional screening as a foundation for developing targeted prevention programs. This is particularly important in the context of an aging population. In Belgium, for instance, expectations are that by 2040, 37 out of 100 citizens will be aged 67 or older and by 2070 this will be 43 out of 100 (Kondi et al., 2025) . Falls among older adults are a multifactorial issue with serious implications for public health and society. Improving the prediction and prevention of falls not only enhances individual quality of life but also helps alleviate pressure on the healthcare system, contributing to more sustainable healthcare outcomes.

The most notable result was a significantly slower Reaction Time in fallers compared to non-fallers. This result supports earlier findings in the literature, where it is stated that a slower ability to react is an important risk factor for falls in older adults (Delbaere et al., 2010). However, the small sample size (n = 73) used in our study combined with a limited number of fallers (n = 10), makes it difficult to generalise this conclusion. A few outliers, such as a participant with an exceptionally low Reaction Time compared to the rest, can significantly influence the average mean, which may explain the observed significance. This hypothesis is confirmed when looking at the results for Reaction Time in Table 1. The median of the fallers (score = 93) is higher than the median of the non-fallers (score = 77), meaning that the fallers are able to react quicker. These findings are similar for the parameter TUG, where the median score for the fallers (score = 5.655) is faster than the score for the non-fallers (score = 5.97). This also applies for the parameters Quadriceps Strength and Handgrip Strength where the mean scores are higher for the fallers group, which one would not expect.

### *Limitations*

The high theoretical sensitivity of the model did not translate into accurate real-world predictions. Only two of the actual fallers were correctly classified. This problem indicates that the model is not capable to really capture the complexity of risk of falling, due to its classification threshold or the underlying assumptions. Consequently, only two true positives were detected by the model, which is an essential requirement for any reliable screening tool. This results in eight false negatives. Based on these findings, the model has limited practical use for identifying an increased risk of falling in healthy older adults.

Another important limitation of this study is the possibility of selection bias. The participants were recruited on a voluntary basis, which led to an overrepresentation of physically active older adults who wanted to demonstrate their level of fitness and prove themselves. In addition, based on the exclusion criteria of the study, individuals with chronic conditions were excluded from the study even though literature shows that we can often associate these conditions with an increased risk of falling (Bailey, 2023; Gezondheid en wetenschap, 2022). This may result in underrepresentation of people who do have an elevated risk of falling, who are often less mobile or have less confidence in their abilities. This factor also complicates the possibility to detect significant differences between groups and may limit the validity of our study.

Additionally, there was a possibility of inter-rater variability. Even though the testing procedure was standardized with the same equipment, the study was conducted by a team of seven researchers and students. This may have led to small variations in measurement results because of subtle differences in instructions, test administration and participant motivation. This might have affected the internal reliability of the study.

During the study, some problems were encountered using technology as measurement devices. Some equipment relied on a stable internet connection, which in some cases led to the loss of data or incorrect measurements. Although we believe that technology is a valuable tool in research and can provide objective data, this emphasizes the importance of technical reliability and backup systems in these research settings.

The JMP Pro 17 software was used for the statistical analysis. Although this is a user-friendly program, it has limited capabilities for more advanced analyses such as exact non-parametric tests (Wilcoxon exact test), which could have limited the statistical depth of the research. Moreover, the analyses were conducted by students with only basic knowledge of statistics which may have affected the interpretation and processing as well as the formulation of more complex models.

### *Strengths*

Though, this study also has some strengths. The multidimensional character of the testing protocol, which takes not only physical but also functional and cognitive aspects into account, aligns with recent insights that falling is determined by multiple factors. The usage of standardized reference values to interpret the absolute scores of some tests also increases comparability.

### *Future research*

The authors of this study believe that future research should focus on larger samples with a more diverse population, including older adults with an increased risk of falling. More reliable data can be obtained when using more advanced technologies with a more standardized protocol, with fewer different researchers. Furthermore, a longitudinal design that also prospectively records falls would allow for a clearer understanding of the factors contributing to these falls.

Finally, the results demonstrate the potential of reaction time as a screening parameter for fall risk, but further validation through future research is required.

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# Appendix A

**Table A**

*Confusion matrix of the fall prediction model based on multiple logistic regression*

| **Actual Fallers** | **Predicted Count** | |
|---|---|---|
| | 1 (Faller) | 2 (Non-Faller) |
| 1 (Faller) | 2 | 8 |
| 2 (Non-Faller) | 1 | 62 |

*Note. IDs of actual fallers: 5, 10, 24, 41, 45, 49, 54, 59, 68, 72; IDs of predicted fallers: 25, 41, 59*