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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Proprioception in school-aged typical developing children: ankle and hip proprioception and the correlation with balance performance

Kaat Lauwers
Lien Verecken
Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij kinderen

PROMOTOR :
Prof. dr. Pieter MEYNS

BEGELEIDER :
Mevrouw Nina JACOBS

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We would like to thank several persons, without their help, support and feedback we would not have been able to accomplish this master thesis.

First we will thank our promotor Prof. Dr. Meyns Pieter for his support this entire year and his feedback for making a better end product. Secondly, we would like to thank our supervisor, Miss. Jacobs Nina for her guidance throughout the whole process of our master thesis. Also for the brief follow-up during the development of our master thesis and her immediate and comprehensive feedback. We would always count on her for answering all of our questions. Further, she was also responsible for the preparation of the smooth-running measurements. Miss. Jacobs Nina put us as well in contact with Dr. Verbeqcue Evi. We would like to thank her for counselling us into the renewed Kids Balance Evaluation Systems Test (Kids-BESTest). In addition, a big thanks to the University of Antwerp for using their M²OCEAN lab, and the university of Hasselt to make use of the Grail. Without the clinical trial centres we would not be able to obtain all the correct data.

Lastly, we are much obliged to all our participants who volunteered in our research. We are very grateful that they were willing to make time and effort for helping us with the data-acquisition. Also, specifically a thank you to the participants parents for their flexibility in the arrangements of the test moments.

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Research context

This is a pilot study within the research domains of paediatrics and biomechanics. The purpose of this study is to identify proprioceptive development in relation to age and whether this is correlated with balance performance. If there is a correlation found, it would become a fundamental part of the clinical testing and treatment of balance problems. Therefore it is valuable to know whether or not proprioception is a factor that impacts balance performance. At the moment, proprioception is not routinely directly assessed during clinical examination and treatments. Mainly an indirect method for measuring proprioception is used, specifically observation (Chu, 2017; McLaughlin, Felix, Nowbar, Ferrel, Bjornson & Hays, 2005).

Hopefully, this pilot study will generate further research on the subject of the relation between proprioception and balance performance. When this is positive it will be crucial having a norm reference in typically developing (TD) children. This is necessary since a deficit in proprioception can only be found clinically important when it is known how proprioception varies in TD Children before comparing the results to other pathologies.

Through the experience of this pilot study, advice for further research about this topic is put together. Additionally, the method of test administration was shared so it could be implemented in more extensive research. This study will be executed as a duo-master thesis in 2021-2022 as part of a bigger four year "Doctor of Philosophy" (PhD) project of Miss. Jacobs Nina. This PhD project covers three different parts. First, an observational case-control study (correlation between proprioception and balance in children with Cerebral Palsy (CP). Secondly, a retrospective study namely a classification of brain lesion characteristics in relationship to balance. And thirdly, a quasi-experimental study (effect muscle fatigue on balance and proprioception). The study has multicenter ethical approval, the Belgian registration number is: B3002021000145. For validation of the study in university hospitals, the numbers are: EDGE-nummer (UZA): 001548; S-nummer (UZ Leuven): S65081.

First, this master thesis was determined to be an observational case control study of children in CP. Afterwards, there was a shift of subject due to the delayed ethical approval of Miss. Jacobs Nina her PhD project. There was a choice between two different options: correlation between balance and proprioception in healthy children or a case-control study by scoring balance data out of previously recorded videos of CP children and healthy children. Because of our interest in proprioception data, the first option was chosen. This is an observational study, where the established testmethod of miss. Jacobs Nina was used. First, the recruiting was started on the first of march, six out of fifteen participants were recruited by L.K. and V.L. The data-acquisition is started the 23the of march where both have assisted in, together with 1e master students in attendance of Miss. Jacobs Nina. Not only did we assist in measurements which are relevant to our master thesis. Part three of the PhD project was assisted by us as well as a second measurement of the first part for checking the inter-rater reliability. The rough data of proprioception for calculating the joint reposition error was analysed by Miss. Jacobs Nina. This, because there was no possibility to process this ourselves due to the accessibility of the analysing program. Further analysis of proprioception data, namely the mean and standard deviation are done independently. The Kids Balance Evaluation Systems Test (Kids-BESTest) was continuously performed by Miss Jacobs Nina. Afterwards, the data-acquisition was performed by L.K. and V.L. through the use of recorded videos. During the writing process we were assisted by Miss. Jacobs Nina, through feedback on independently written parts of our article. This was both written and oral comments during an online meeting.

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Proprioception in school-aged typical developing children: ankle and hip proprioception and the correlation with balance performance

1. Abstract

Background: Both proprioception and balance are still developing during childhood and slowly stabilising in adolescence. Further, proprioception is one of the three important factors to maintain balance. This correlation is mainly investigated in the upper limb and in single-joints.

Objectives: (1) the proprioception of both dominant and non-dominant body side in both ankle and hip joints and age; (2) balance performance and chronological age and (3) balance performance and proprioception of both dominant and non-dominant body side in both ankle and hip joints.

Participants: There are fifteen participants of which eight boys and seven girls. Their age lies between six and ten years old and 80% were right handed.

Measurements: To measure the proprioception of the dominant and non-dominant body side of both the hip and ankle a passive joint position reproduction protocol was used. The exact joint angles were calculated with the use of the 3D analysis 'Vicon' was used. Balance was measured with the Kids-BESTest.

Results: (1) A significant correlation was found for the ankle and hip joints both on the dominant and non-dominant body side (2) only a significant correlation between domain two of the Kids-BESTest and age (3) no significance was found except in domain three of the Kids-BESTest.

Conclusion: In this study a significant correlation was found between age with proprioception and age with anticipatory balance performance. Both proprioception and anticipatory balance performance increased with age. The correlation between proprioception and balance performance was found not significant except in domain three 'Transitions and anticipatory postural adjustments' of the Kids-BESTest. Therefore, it is unclear whether proprioception correlates with all balance domains. Further large-scale research is needed for a more comprehensive analysis about this topic and to check if there is an interaction effect from proprioception on balance performance.

Keywords: children, proprioception, balance, normal development

2. Introduction

Proprioception, which compromises the joint position sense or stathesthesia and joint movement sense or kinesthesia, is the ability to sense body movements as well as the position of the body, or body parts, in space without the use of vision and the position of body parts relative to each other (Grossman, & Porth, 2013).

This proprioceptive information is gathered by input from receptors in the muscles (i.e. muscle spindles), tendons (i.e. Golgi tendon organs), joints and skin (i.e., mechanoreceptors) (Lundy-ekman, 2017; Shumway-Cook, & Woollacott, 2016). During limb movement, the tissues of these body structures (with the embedded receptors) are deformed, forwarding proprioceptive signals through different afferent peripheral neurons. When afferent neurons enter the spinal cord, they connect with 2 different neurons: at the lowest level, they converge on spinal interneurons (short-loop spinal reflex pathway) and at the highest level, they are carried over different parts of the brain (long-loop transcortical pathway). The spinal reflex pathway gives a direct response to the incoming sensory information and produces a motor impulse. This myotatic or stretch reflex controls both muscle tone and helps maintain the posture. The neurons of the transcortical pathway transmit the signals out of proprioceptive receptors through the dorsal column-medial lemniscus pathway to the thalamus before reaching the cortical (somatosensory cortex) and subcortical (cerebellum and basal ganglia) structures, thus creating limb-position related feedback. (Grossman et al., 2013; Lundy-ekman, 2017; Shumway Cook et al., 2016; Mackinnon, 2018).

During childhood, proprioception is still developing with slowing improvement and stabilisation in adolescence. In early childhood, studies have shown that proprioceptive accuracy (i.e. accuracy in actively matching joint positions) develops rapidly from three to six years old (Jiang, Jiao, Wu, Ji, Liu, Chen & Wang, 2018). Later in life during adolescence, proprioception, namely in kinesthesia in both upper and lower limb, is still developing but will slowly reach a plateau (Dunn, Griffith, Morrison, Tanquary, Sabata, Victorson, Carey, Gershon, (2013); Dunn, Griffith, Sabata, Morrison, MacDermid, Darragh, Schaaf, Dudgeon, Connor, Carey & Tanquary, (2015); Taylor, McLean, Falkmer, Carey, Girdler, Elliott & Blair (2016); Marini, Squeri, Morasso, Campus, Konczak & Masia (2017); Davies, Parsons & Tan (2020); Yang, Waddington, Adams & Han (2019); Jiang et al., 2018). Most research about the development of proprioception has analysed the upper limb, studies about the lower limbs are mainly single joint studies. That is why age should be a factor that is considered when measuring and comparing multi-joint proprioception in the lower limbs.

Furthermore, proprioception is known to play an integral role in balance control. To keep a state of balance, the body needs an accurate perception of where the body is located in space and how the different body segments are positioned with respect to each other. To establish this internal schema the cerebral cortex incorporates feedback from three different systems. One of them is the proprioceptive system which co-operates with the two other systems (i.e. vestibular system and vision). When two out of three systems are intact no effect is shown in balance control, the unreliable one can be compensated for by the two others (sensory reintegration) (Shumway et al., 2016). Whereas when two sensory functions give no reliable input the balance control is decreased. Walking, running, swimming, ball games, ... are all activities which require good balance control. This in turn determines the Quality of Life (QoL) (Saavedra, & Goodworth, 2020). Balance can be defined as "The inherent ability of a person to maintain, achieve or restore a specific state of balance and not to fall. The inherent ability refers to the motor and sensory systems and to the physical properties of the person." (Pollock, Durward, Rowe, & Paul, 2000).

The balance control consists of three states. The first is the 'steady-state balance'. This is often referred to as 'static balance' because the Base of Support (BOS) is not moving or changing. A second state of balance is the 'reactive-balance control'. This is the response to brief displacements of the Centre of Mass (COM) on the BOS using a variety of motor strategies. Lastly there is the 'proactive- or anticipatory-balance control'. This is an anticipatory reaction to disturbances of balance and is based on previous experiences throughout our lives. These different states can be disrupted due to problems in proprioception. If there is an interruption in the short-loop spinal reflex pathway it will result in a problem with anticipatory balance. If the problem lies higher, in the long-loop transcortical pathway, it will impact the reactive balance control. (Shumway-Cook et al., 2016)

In addition, literature depicts that our balance control also improves with age between four-year old and twelve-year old children (Kolic, O'Brien, Bowles, Iles & Williams, 2020; Jiang et al., 2018) Other studies show also a difference in development between age of dynamic and static balance control (Conner, Petersen, Pigman, Tracy, Johnson, Manal, Miller, Modlesky & Crenshaw, 2019).

Since we know that both proprioception and balance are still developing this could be correlated but there is not enough research on balance and proprioception in typically developing (TD) children. Therefore, this study will investigate the influence of age on both proprioception and balance and the correlation between proprioception and balance.

3. Methods

This study is an observational study focusing on proprioception of the ankle and hip joint of typically developing children, and the relationship between proprioception and balance.

2.1 Participants

2.1.1 Selection criteria

The study sample consisted of TD children aged six to ten years old. Children were included or excluded based on the selection criteria summarised in table 1.

Table 1: Selection criteria of Typically developing children

Inclusion criteria	Exclusion criteria
Age 5-10 years	Developmental disorders (e.g. developmental coordination disorder)
Born > 37 weeks of gestation	Prematurity (born < 37 weeks of gestation)
IQ ≥ 70	Intellectual delays (IQ < 70)
	Visual or vestibular impairments
	Neurological, orthopaedic or other medical conditions that might impede balance control

Abbreviations: IQ = intellectual quotient

2.1.2 Recruitment

The participants were recruited from the researcher's environment, starting March 2022. Before the testing took place, the parents of the child agreed with the test procedure signing the informed consent.

2.2. Materials and procedures

After agreement of the test procedure, ankle and hip proprioception as well as balance performance were determined in TD Children. Measurements were taken in one of the following locations (3D movement laboratories), depending on the parents' choice: the university Hospital of Antwerp (UZA) (M²OCEAN lab UAntwerpen, Campus Wilrijk) or the university of Hasselt (GRAIL, UHasselt, wetenschapspark Diepenbeek). The same measurement procedures were carried out at the different participating sites (see 2.2.1 proprioception procedure and 2.2.2 balance performance).

2.2.1 Proprioception procedure

Lower limb proprioception was assessed in terms of joint position sense of the hip and ankle joint. The most feasible and accurate testing method to measure this is the joint position reproduction (JPR) protocol, also known as joint position matching (Han, Waddington, Adams, Anson, Liu, 2016; Elangovan, Herrmann, Konczak, 2014). The ipsilateral JPR task was chosen to be performed.

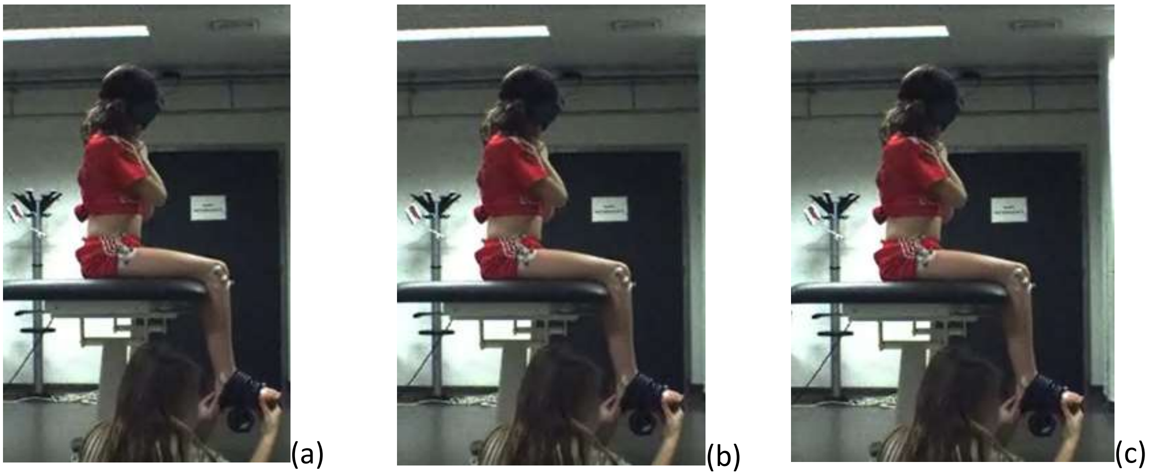
All JPR tasks started in a seated position. For the hip the children were seated on an inclined surface (30°) so that the hip range is larger, see figure 1. One reference joint position (target) for each joint was determined in advance (hip joint = 90° flexion, ankle joint= 30° plantar flexion). During the JPR protocol, children were asked to actively reproduce a passively determined joint position as accurately as possible with the same limb in the sagittal plane. The JPR test procedure was performed in the sagittal plane because of the importance of the movement direction in functional tasks and mobility and since the largest range of motion is situated in this direction (Neuman, 2017; shumway cook, 2016).

This proprioception protocol consisted of three phases: (1) experience, (2) memory and (3) reproduction, defined as followed:

1. *Experience:* The examiner positioned the child's tested joint in a specific, predetermined joint angle (i.e., reference joint position), using an inclinometer, starting from a neutral starting position. See figure 1 (a,d)
2. *Memory*: After experiencing and memorising the reference joint position for five seconds, the examiner returned the joint back to the neutral start position. See figure 1 (b, e)
3. Reproduction: The examiner moved the tested joint again over the total range of the joint. When the predetermined position was passively reproduced the child needed to press on a button. See figure 1 (c, f)

Testing was repeated three times for both the dominant and non-dominant limb. During the JPR task the child is blindfolded to ensure solely proprioceptive input is used. To make sure that the participants understood the instructions, a practice trial was allowed with their eyes open. In order to minimise a learning effect this has always been kept to a limited number. All JPR tasks were performed by one examiner during a one hour protocol. The JPR task phases are visualised in Figure 1.

Proprioception ankle joint



Proprioception hip joint

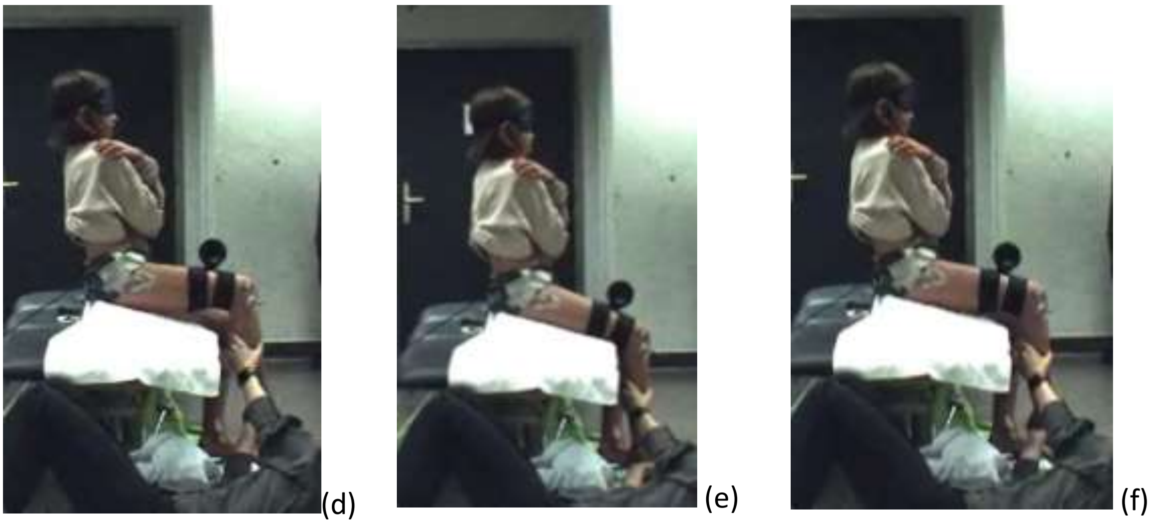


Figure 1: *(a,d) ankle was passively positioned in a predetermined joint-angle (experience), (b,e) ankle passively returned to neutral position (memory), (c,f) the child pressed a button when the examiner passively recreate the reference position in the ankle (reproduction)*

Outcome parameter:

For the JPR method, the absolute joint reproduction errors (JRE) (in degrees) between the determined target and the reproduced joint angle were used as an outcome measure of JPS accuracy. This absolute JRE was calculated from 3D kinematics using the Vicon camera 3D motion analysis system (Oxford). From the absolute JRE score the mean was calculated of the three trails from each limb. A higher mean score of JRE in degrees translates to more difficulties the participant has with the reproduction of the correct joint angle in their tested limb. Further a high standard deviation (SD) signifies that there is a high difference between the JRE of the three trails from the same joint. The joint angles were calculated with the use of 26 reflective markers which were placed on the child's body. These markers were located on predetermined anatomic landmarks of the lower limb from the recommendations of the International Society of Biomechanics (ISB) (Wu, Siegler, Allard, Kirtley, Leardini, Rosenbaum, Whittle, D'Lima, Cristofolini, Witte, Schmid, Stokes, 2002). 3D full body kinematics were obtained via computer-based tracking of the different reflective markers to measure the joint angles.

2.2.2 Balance performance

Balance control consists of three states: steady-state, reactive and anticipatory balance (Shumway-Cook, 2016; Horak, 2006; Horak, Wrisley & Frank, 2009). All three states of balance are integrated into the Kids Balance Evaluation Systems Test (Kids-BESTest). Next to the three stages the Kids-BESTest also integrates sensory integration strategies and control of dynamics during gait which is also an important factor of balance performance (Horak, 2006; Horak, Wrisley & Frank, 2009). Therefore, the Kids-BESTest was used for assessing balance performance (Dewar, Claus, Tucker, Ware, & Johnston, 2017).

The Kids-BESTest is a clinical test which contains 36 tasks which were scored on a 4-point scale with a maximum score of three points (best performance) to zero points per item (worst performance). The different tasks are divided into six balance domains: biomechanical constraints (5 tasks), reactive postural responses (6 tasks), anticipatory postural adjustments (6 tasks), stability limits/verticality (7 tasks), sensory orientation (5 tasks), stability in gait (7 tasks). The test order of all domains were randomised. Otherwise, all participants would end with the same domain whereby fatigue could play a role in the results.

To ensure consistency across the examiners, administration and scoring, a training was organised. Thereby maximising the intra-rater reliability. The tests were done by only one examiner to eliminate the inter-rater reliability. The Kids-BESTest was administered in a laboratory setting with a test duration of approximately 30 minutes. Afterwards, balance performance was scored independently by two master students in the rehabilitation science (paediatrics). The scoring of each child's performance on the Kids-BESTest was done afterwards on the basis of a video recording (Dewar, Claus, Tucker, Ware, & Johnston, 2019). If there was a disagreement in the scoring of the Kids-BESTest, both evaluators met and discussed the data until a consensus was reached. The kids-BESTest has an excellent intra-rater reliability ([ICC] 0.92-0.98) for the video assessment. In other words, the kids-BESTest is a reliable tool both when administered on different days when a video assessment is used.

Outcome parameter:

The outcome measures of the kids-BESTest could be interpreted as a total score (0-180), each subdomain individually or each clinical item separately (0-3). In this research the total score and individual subdomain scores were used.

The raw data of the Kids-BESTest were converted into percentages for both the total score and all subdomains except the first domain, addressing the biomechanical constraints. This was not discussed in this research as it does not provide information on balance control, but rather on musculoskeletal requirements.

2.3 Data-analysis

For proprioception, the absolute JRE (in degrees, °) between the target and reproduction joint angle was defined for each trial. Vicon Nexus 2.12.1 and Matlab R2022a (Mathworks, Natick, MA, USA) were used for further data processing and filtering of the raw data. The mean of the three JRE was defined and used for further analyses.

For balance performance, domain and total (0-105) scores were calculated based on different item scores. For each domain the scores were represented in percentages. This was done because of the different age bands in the Kids-BESTest. Therefore, not all participants had the same amount of test items per domain. The percentages were calculated by dividing the overall domain score by the number of test items per domain.

Chronological age was calculated by subtracting the day of the test and the day of birth. Each month compromised 30 days in the calculation. The chronological age was presented as years, $\frac{(\text{months x } 30 + \text{days})}{360}$.

2.4 Statistic analysis

Population characteristics (i.e. sex, age, weight, length) were analysed using descriptive analysis. The proprioception and balance outcome measures together with age were analysed using the Statistical Software program "JMP pro 16".

Pearson correlation coefficients were used to determine the relationship between (1) the proprioception of both dominant and non-dominant body side in both ankle and hip joints (JRE [°]) and age (years); (2) balance performance (total and domain scores [%]) and chronological age (years) and (3) balance performance (total and domain scores [%]) and proprioception of both dominant and non-dominant body side in both ankle and hip joints (JRE [°]). If the data for the Pearson correlation coefficient was not normally distributed, Spearman's rank correlation analysis would be performed.

All except the first domain of the Kids-BESTest were used in the analysis for both research question two and three. The different correlations were compared to each other because it is expected that in some domains there was a higher correlation with proprioception than others.

In order to assess the strength of the correlation, the correlations were divided according to Schrober et al. (Schober, Boer, Schwarte, 2018) which is presented in table 2. A significance level of $p<0.05$ was used for all performed analysis.

Table 2: Interpretation Pearson Correlation Coefficient

Negligible	0,0 -0,10
Weak	0,10-0,39
Moderate	0,40-0,69
Strong	0,70-0,89
Very strong	0,90 -1

3. Results

3.1 Population characteristics

Fifteen typically developing children (mean age 7.827 ± 1.162, 8 boys/7 girls) participated in this study. The ages ranged from 6 to 10 years with an age difference of 4 years between the youngest (six years, seven months and fourteen days) and the oldest child (ten years, nine months and nine days). The majority of the participants (80%) have the right side as their dominant body side. Further, both the body mass (mean 6kg ± 4kg) and height (mean 0.91m ± 0.1m) were measured. A more detailed overview of the subject characteristics is displayed in table 3.

Afterwards, one child was excluded from the balance performance data set and the associated correlation analyses, since the measurement of balance performances must be interrupted.

Table 3. Subject characteristics

	Chronological age	Gender	Dominant side	Body Mass (kg)	Height (m)
01	6.62	Girl	Right	19.6	1.15
02	6.96	Boy	Right	24.6	1.31
03	7.27	Boy	Right	21.6	1.20
04	7.85	Boy	Left	24.6	1.26
05	7.93	Girl	Left	26.8	1.34
06	7.94	Girl	Right	33.7	1.39
07	8.29	Girl	Left	27.6	1.34
08	8.10	Girl	Right	31	1.39
09	8.17	Boy	Right	26	1.33
10	8.74	Boy	Right	26.9	1.38
11	9.06	Girl	Right	32.2	1.43
12	9.19	Girl	Right	34	1.43
13	9.77	Boy	Right	45.2	1.47
14	9.78	Boy	Right	46.3	1.42
15	10.77	Boy	Right	36.5	1.51

Abbreviations: kg = kilogram; m = metre

3.2 Correlation between proprioception and age

For the dominant and non-dominant hip joint, the JRE has a mean of 3.88° ± 1.24 and a mean of 3.99° ± 1.62, respectively, with lower JRE values as age increases. Pearson correlation coefficients (r) between JRE of the hip and chronological age were strong both on the dominant ($r = -0.704$, $p<0.01$) and non-dominant body side ($r = -0.722$, $p<0.01$).

For the ankle joint, the JRE has a mean of 4.90° ± 2.09 on the dominant side and a mean of 5.67° ± 3.26 on the non-dominant side of the body. Also, a strong negative correlation between JRE of the ankle and chronological age was shown for both legs (dominant ankle joint: $r = -0.8995$, $p<0.01$, non-dominant ankle joint: $r = -0.8415$, $p<0.01$)

For each child, the mean values of the joint reproduction error (JRE) for the hip and ankle joint, both on the dominant and the dominant body side, are shown in table 4 according to their chronological age. To visualise (the strength) of the relations, scatter plots are displayed in Figure 2 together with the corresponding Pearson correlation coefficients (r).

Table 4: Case report of the absolute joint reproduction error (in degrees) by joint and limb preference according to the chronological age

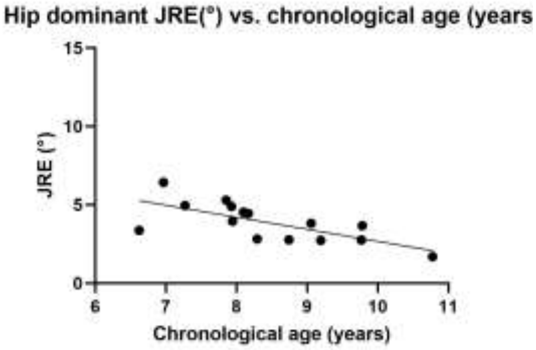
		Dominant side		Non dominant side	
		Hip	Ankle	Hip	Ankle
	Chronological age	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
01	6.62	3.37° ± 1.58	9.47° ± 3.60	7.22° ± 2.01	11.80° ± 5.83
02	6.96	6.43° ± 2.35	7.76° ± 1.44	6.91° ± 3.79	13.20° ± 3.23
03	7.27	4.95° ± 1.45	5.90° ± 0.61	5.13° ± 0.34	6.15° ± 2.31
04	7.85	5.29° ± 0.76	6.43° ± 4.40	5.83° ± 4.15	8.00° ± 4.99
05	7.93	4.89° ± 2.51	6.17° ± 3.40	4.54° ± 1.84	6.07° ± 5.16
06	7.94	3.95° ± 1.42	5.58° ± 4.20	3.19° ± 2.21	6.99° ± 1.95
07	8.10	4.53° ± 1.24	5.79° ± 1.90	3.88° ± 2.66	5.87° ± 2.74
08	8.17	4.45° ± 1.24	5.33° ± 4.33	3.47° ± 1.88	3.81° ± 1.59
09	8.30	2.82° ± 2.83	3.57° ± 0.36	3.30° ± 2.01	4.57° ± 1.50
10	8.74	2.77° ± 2.07	3.24° ± 2.14	3.55° ± 0.83	4.27° ± 1.44
11	9.06	3.82° ± 2.31	3.05° ± 1.57	2.74° ± 0.14	3.45° ± 1.30
12	9.19	2.73° ± 3.12	2.82° ± 1.24	2.60° ± 0.76	2.84° ± 0.77
13	9.77	2.76° ± 2.48	2.61° ± 2.68	2.42° ± 1.09	2.25° ± 2.77

14	9.78	3.67° ± 1.10	3.47° ± 0.65	3.19° ± 1.66	3.42° ± 2.00
15	10.78	1.69° ± 0.19	2.37° ± 1.79	1.88° ± 1.87	2.43° ± 1.41

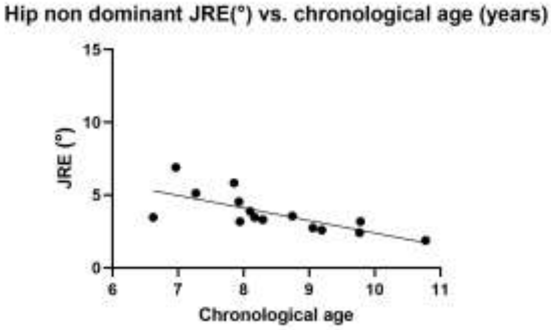
Abbreviations: SD = standard deviation; ° = degrees
The mean JRE value represents the absolute average value across repeated trials within one age-case. Perfect ankle or hip position reproduction would yield a JRE value of zero

Figure 2: Correlation between age and JRE

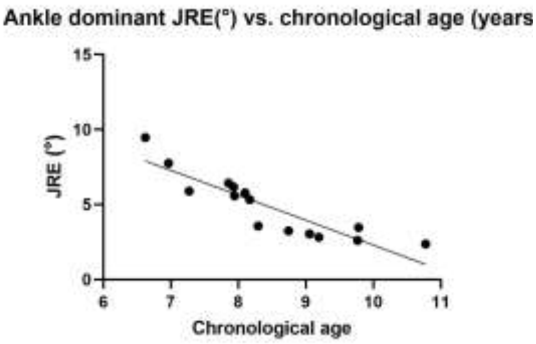
Hip dominant
r = -0,7036
p = 0,0034
[-0,8937; -0,2991]



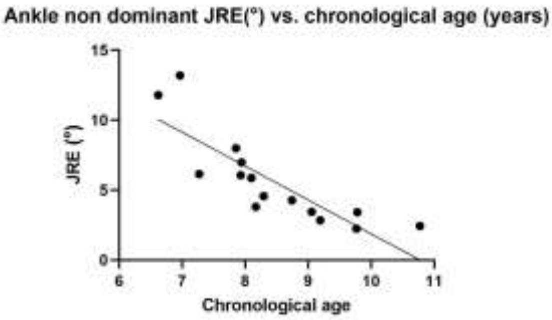
Hip non-dominant
r = -0,7218
p = 0,0024
[-0,9009;-0,3324]



Ankle dominant
r = -0,8995
p = 0,0001
[-0,9664; -0,7181]



Ankle non-dominant
r = -0,8415
p = 0,0001
[-0,9460; -0,5788]



Abbreviations: r = Pearson Correlation Coefficient; p = p-value (significance level $p < 0,05$); [ ] = 95% confidence interval [lower bound - upper bound]; JRE (°) = joint reposition error in degrees

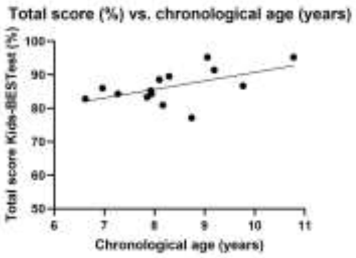
3.3 Correlation between balance performance and age

For balance, measured with the Kids-BESTest, a positive correlation and all domains except for domain five which has a negative correlation (r = -0.3482) correlation according to Schrober et al. (Schober, Boer, Schwarte, 2018). All correlations except domain three were weak, domain three has a moderate correlation (r = 0.5585).

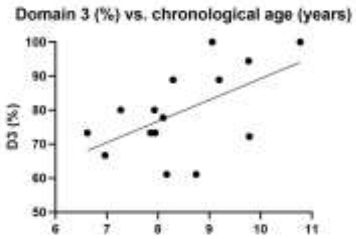
Percentile scores (%) of domain 3 were significantly correlated to age, reflecting better balance performance during tasks requiring anticipatory postural adjustments with increasing age. However, regarding the percentile scores (%) of domain 2 (limits of stability and verticality), domain 4 (reactive postural responses) and domain 6 (stability in walking), no significant correlation with age was shown (p<0.05). The exact scores and percentages of each child on the Kids-BESTest are displayed in table 7. This is further visualised in figure 3.

Table 8: Correlation between age and Kids-BESTest

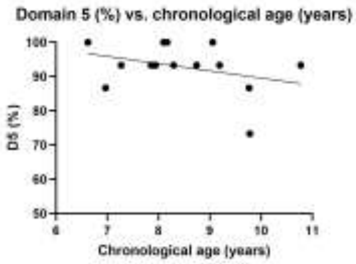
Total score
r = 0.2837
p = 0.0415*
[0.0277; 0.8366]



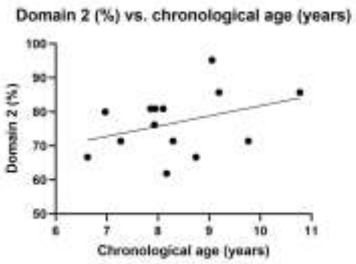
Domain 3
r = 0.5585
p = 0.0305*
[0.0648; 0.8326]



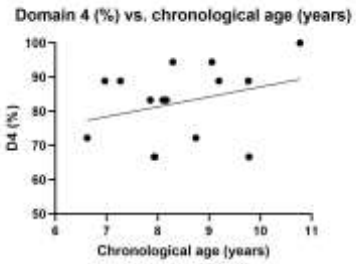
Domain 5
r = -0.3482
p = 0.2035
[-0.7302; 0.1997]



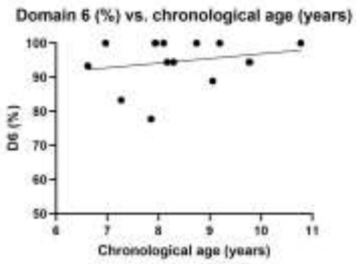
Domain 2
r = 0.2634
p = 0.1989
[-0.2049; 0.7505]



Domain 4
r = 0.2971
p = 0.2823
[-0.2538; 0.7024]



Domain 6
r = 0.2273
p =0.4152
[-0.3225; 0.6624]



Abbreviations: r = Pearson Correlation Coefficient; p = p-value; * significant p-value <0.05; Domain 2 = "Limits of stability and verticality"; Domain 3 = "Transitions and anticipatory postural adjustments"; Domain 4 = "Reactive postural responses"; Domain 5 = "Sensory orientation"; Domain 6 = "Stability in gait"

Table 7: Balance outcomes from the Kids-BESTest represented in point score and their percentages

	Chronological age	Domain 1		Domain 2		Domain 3		Domain 4		Domain 5		Domain 6		Total score	
		Score	Percentage	Score	Percentage	Score	Percentage	Score	Percentage	Score	Percentage	Score	Percentage	Score	Percentage
1	6.62	14	93%	10	67%	11	73%	13	72%	15	100%	14	93%	77	83%
2	6.96	14	93%	12	80%	10	67%	16	89%	13	87%	15	100%	80	86%
3	7.27	14	93%	15	71%	12	80%	16	89%	14	93%	15	83%	86	84%
4	7.85	14	93%	17	81%	11	73%	15	83%	14	93%	14	78%	85	83%
5	7.93	15	100%	16	76%	12	80%	12	67%	14	93%	18	100%	87	85%
6	7.94	14	93%	17	81%	11	73%	12	67%	14	93%	18	100%	86	84%
7	8.10	14	93%	17	81%	14	78%	15	83%	15	100%	18	100%	93	89%
8	8.17	14	93%	13	62%	11	61%	15	83%	15	100%	17	94%	85	81%
9	8.29	15	100%	15	71%	16	89%	17	94%	14	93%	17	94%	94	90%
10	8.74	11	73%	14	67%	11	61%	13	72%	14	93%	18	100%	81	77%
11	9.06	14	93%	20	95%	18	100%	17	94%	15	100%	16	89%	100	95%
12	9.19	14	93%	18	86%	16	89%	16	89%	14	93%	18	100%	96	91%
13	9.77	13	87%	15	71%	17	94%	16	89%	13	87%	17	94%	91	87%

14	9.78	14	93%	0	0%	13	72%	12	67%	11	73%	17	94%	67	64%
15	10.77	14	93%	18	86%	18	100%	18	100%	14	93%	18	100%	100	95%

Abbreviations: Domain 1 = “Biomechanical constraints”; Domain 2 = ”Limits of stability and verticality”; Domain 3 = “Transitions and anticipatory postural adjustments”; Domain 4 = “Reactive postural responses”; Domain 5 = “Sensory orientation”; Domain 6 = “Stability in gait”

3.4 Correlation between proprioception and balance performance

The correlation of proprioception (JRE °) and balance (%) of both the total score and all subdomains of the Kids-BESTest were calculated. An overview of the Pearson's Correlation Coefficients can be seen in table 8 together with significance level. These correlations are further visualised in Figure 4.

Table 8: Pearson correlation coefficient between of balance and proprioception

	Proprioception							
	Hip Dominant			Hip Non Dominant			Ankle Dominant	
	r	p	CI	r	p	CI	r	p
Tot. Kids-BESTest	-0.3222	0.2612	[-0.7283; 0.2513]	-0.4145	0.1406	[-0.7747; 0.1488]	-0.4380	0.0940
D2	-0.0036	0.9903	[-0.5331; 0.5280]	-0.1088	0.7112	[-0.6045; 0.4476]	-0.2928	0.2959
D3	-0.5186	0.0574	[-0.8228; 0.0166]	-0.5640	0.0357*	[-0.8425; -0.0476]	-0.5832	0.0261*
D4	-0.2362	0.4162	[-0.6814; 0.3366]	-0.1816	0.5345	[-0.6496; 0.3862]	-0.4811	0.0700
D5	-0.0713	0.8087	[-0.5799; 0.4774]	-0.2778	0.3362	[-0.7045; 0.2965]	-0.0369	0.5443
D6	-0.3012	0.2954	[-0.7171; 0.2731]	-0.3328	0.2450	[-0.7338; 0.2402]	-0.1753	0.5412

3.4.1. Correlation between proprioception of the hip joint and balance

Overall, a tendency for a negative linear relationship between JRE values and balance performance was demonstrated for all joints, meaning that a decrease in JRE values (better proprioception performance) is associated with an increase in the domain as well as total Kids-BESTest percentile score (better balance performance).

The total score of the Kids-BESTest shows a weak correlation in the dominant hip. For the non dominant hip there is a moderate correlation found between the proprioception and balance. But both these correlations are not significant.

Domain two, limits of stability and verticality, of the Kids-BESTest has a negligible correlation in the dominant hip and weak in the non-dominant side. Here, both correlations are not significant. In domain three, transitions and anticipatory postural adjustments, both the dominant and non dominant hip show a moderate correlation, of which the non-dominant side is only significantly important. A weak correlation is found for both body sides in domain four, reactive postural responses, of the hip whose both are not significant. For domain five, sensory orientation, the dominant hip depicts a negligible correlation whereas the non-dominant side shows a weak correlation. Here both are not significantly correlated. Lastly, in domain six, stability in gait, shows a weak correlation for both body sides where again none was significant.

3.4.2. Correlation between proprioception of the ankle joint and balance

All correlations between proprioception and balance concerning the ankle are negatively correlated. This means that a higher score on the Kids-BESTest is associated with a lower JRE in degrees.

Both for the dominant and nondominant ankle joint, a moderate correlation between the JRE values and total Kids-BESTest percentile score is shown. Domain two shows a weak correlation for both ankles. Further, between domain three and proprioception of both ankles is found a moderate correlation of which the dominant ankle is significantly correlated. A moderate correlation is found for both ankles relative to domain four. Towards domain five, the proprioception of the dominant ankle has a negligible correlation and the nondominant side a moderate. At last, between the dominant ankle proprioception and domain six of the Kids-BEStest is found a weak correlation and at the nondominant side a negligible. In the ankle there is only one significant correlation found.

3.4.3. Difference between dominant and non-dominant body side

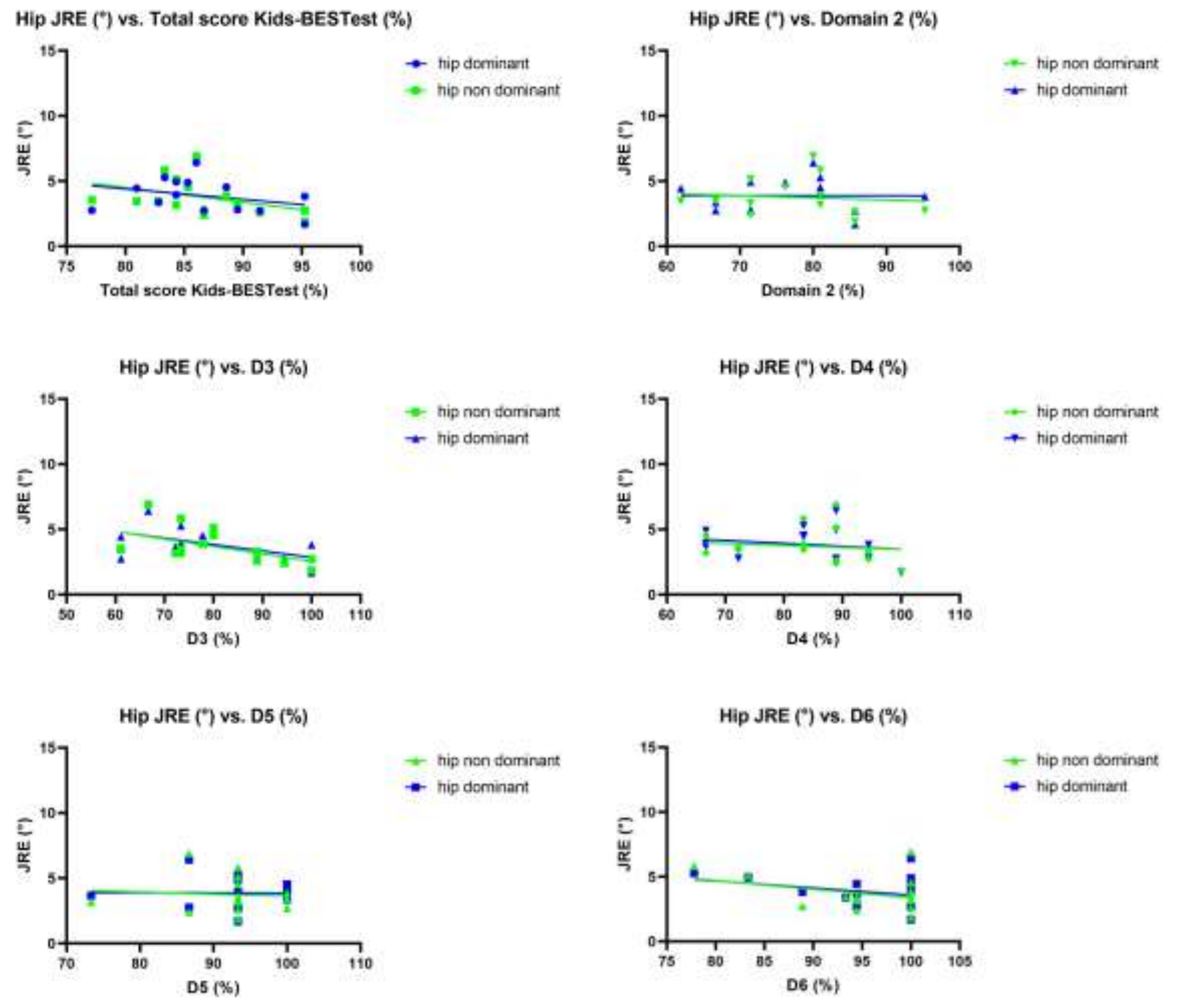
Besides the correlations, the difference between the dominant and non-dominant side is also visualised in figure 4.

When the graphs compare both body sides, a difference is found in performance of both hip joints. Here, the correlation-lines always cross each other, where the non-dominant body side always has a higher JRE for the lower score on the Kids-BESTest than the dominant side. This is for all domains except in domain five 'sensory orientation". In domain five the difference between both lines is less.

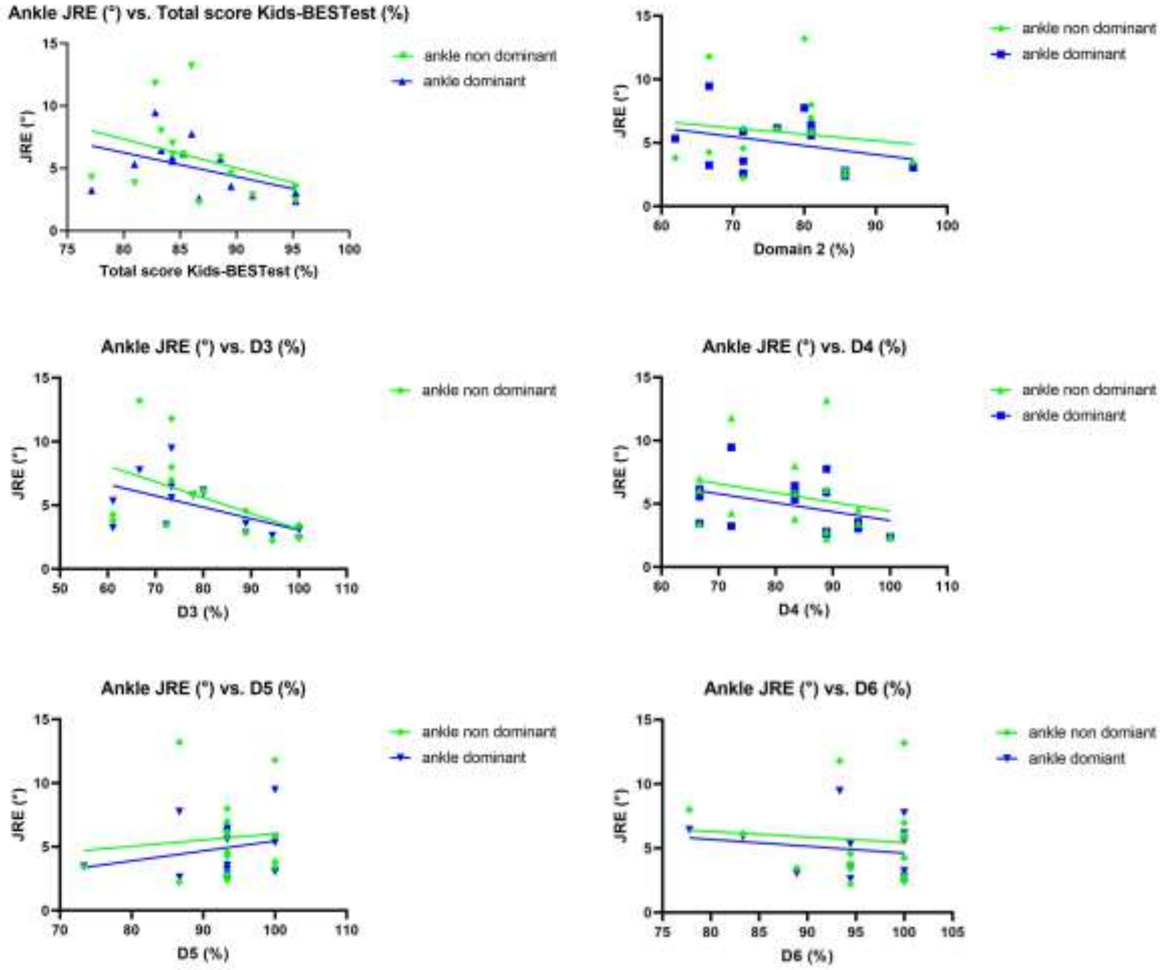
For the ankle joint the correlation-lines only cross in domain three and five. The non-dominant body side has also a higher JRE for the lower score on the Kids-BEStest than the dominant side.

Figure 4: Visualization Pearson Correlation Coefficients

Hip joint



Ankle joint



Domain 2 = "Limits of stability and verticality"; D3 = "Transitions and anticipatory postural adjustments"; D4 = "Reactive postural responses"; D5 = "Sensory orientation"; D6 = "Stability in gait"

1. Discussion

4.1 Reflection on findings in function of research question

The aim of this study was to explore the relationship between balance performance and proprioception of the ankle and hip joint in TD Children aged five to ten years.

Based on these findings, there is found a strong relation between proprioception and age for all tested joints. For the relation between balance and age there is found a positive trend line except in domain five, Sensory orientation. Which shows only a correlation in the total score and during anticipatory balance tasks. Further, in this study, it is plausible that hip and ankle proprioception are associated with balance in TD Children and more specifically during balance tasks that require postural preparations (anticipatory postural adjustments) to execute self-initiated movements, such as standing on one leg or alternating stair touching,...

4.1.1 The development of proprioception and balance

Looking at the significant correlation coefficient, it can be stated that proprioception and age are correlated with each other. This was expected since research shows that proprioception continues to develop until adolescents in both the upper and lower limbs (Dunn et al., 2013; Dunn et al., 2015; Taylor et al., 2016; Marini et al., 2017; Davies et al., 2020; Yang et al., 2019; Jiang et al., 2018). Which is consistent with the findings in this study where this correlation was also depicted in TD Children between the age of five and ten years old. Based on this pilot's study findings, it seems that JPS of the ankle and hip becomes more refined with increasing age (the older the child, the smaller the JRE) which is similar to upper limb JPS maturation (Dunn et al., 2013; Dunn et al., 2015; Taylor et al., 2016; Marini et al., 2017; Davies et al., 2020).

Additionally, balance and age has a tendency to have a significant correlation with each other. There was only a significant interaction between age with the total score and domain three ‘Transitions and anticipatory postural adjustments’ of the Kids-BESTest. Which is not in line with what was expected since we presumed that there would be an interaction between all domains of the Kids-BESTest. This, based on previous research where a significant difference was found (Kolic et al., 2020; Jiang et al., 2018; Conner et al., 2019). This can be explained by the dividing of the Kids-BESTest into age categories, because of the variation between ages which can be explained by immaturity of the balance related systems (Johnson, Meyns, Klingels, Hallemans, 2020). Furthermore, it ensures that the child scores can be compared to those of peers. Another big advantage of the Kids-BESTest is that it includes all 5 different domains of balance in the final score, many others tests only include a few domains in their scoring.

4.1.2 The relationship between proprioception and balance in typically developing children

Based on the results, there is found an overall negative trend for the relation between proprioception and balance. This means that if a child scores worse on proprioception, the child will also score less on balance. This result is in line with earlier research (Jiang et al., 2018). Further, from the results it can be concluded that there is a correlation between the anticipatory balance domain of the Kids-BESTest and proprioception of the non dominant hip and dominant ankle.

The correlation between proprioception and anticipatory balance tasks was expected since this can probably be explained by the feedforward model (Shumway-Cook et al., 2016). Proprioception plays an important role in this feedforward model. The actual sensory feedback, including proprioception, is the feedback from the muscle spindle after conducting a voluntary motor command that transduct through the corticospinal tract to the motor cortex. Previous feedback of earlier experiences is stored in the brain like an efferent copy, which is an internal prediction used to predict consequences of motor output. The feedforward model compares the voluntary motor command with the efference copy to make anticipatory postural adjustments in order to maintain stability during the movement. This feedforward model is important when learning new motor skills, like balance control. Indirectly this means that the immaturity of proprioception (relationship age-proprioception) may indicate immaturity in this feedforward model and thus still more variability in balance performance during anticipatory tasks in de Kids-BESTest. Children are still learning to use a correct strategy, for example to perform a weight shift of one leg to the other in preparation of a single leg stance (Shumway-Cook et al., 2016).

Nevertheless, it was unexpected that only a correlation between balance and proprioception in domain three was pronounced. This correlation was also expected to be found in other domains. This is because proprioception is one of the three important factors to keep your balance (Shumway-Cook et al., 2016; Horak, 2006; Horak et al., 2009). It may be explained by the fact that balance performance was determined based on a clinical rating scale. The Kids-BESTest is a criterium-referred test, which is meant to identify and classify balance deficits in children with pathologies (CP, DCD)(Dewar et al., 2019). Therefore it is expected that 85% of healthy children will have a maximum score, which may differ by up to one standard deviation. Thus, when a child is showing any sign of instability it will not always be visible in the clinical test score due to minimal variability in TD Children. That's why with this outcome measure will find less strong relations but this does not mean that there are none. The results may be more neuro-biomechanical such as the time of onset of the motor response, which is not visible with the clinical rating scale. By using ElectroMyoGraphy (EMG), Center of Mass (COM) and Center of Pressure (COP) you will obtain more information about the used balance strategies.

Steady-state balance will be assessed in the second part of the kids-BESTest (Limits of stability and verticality). Although proprioception is needed for a good balance performance, there is no correlation found between this part of the Kids-BESTest and proprioception. This can be explained because the function of the proprioceptive system can be compensated by both the balance organ and vision. (Shumway-Cook et al., 2016)

Further, the relationship between proprioception and reactive balance, which is tested in the fourth part of the Kids-BESTest, has a negative trend-line. This can be explained by the role of proprioception in the feedback mechanism. This mechanism is used to maintain reactive balance control. When there is an external perturbation of the postural balance, a response occurs based on sensory feedback (visus/vestibular/proprioceptive). This response is done through the use of a variety of motor strategies. There are three different strategies identified: the ankle strategy, the hip strategy and the step strategy. The step strategy is mainly used when the hip and ankle strategy are not sufficient. In the results a more negative trend-line is seen in the ankle joint which may indicate greater reliance on the ankle strategy. That's why there is a smaller relationship between proprioception of the hip and reactive balance (Shumway-Cook et al., 2016).

Additionally, sensory integration is very important in the fifth part (sensoric orientation) of the Kids-BESTest. In this part only the closed-eye condition on the foam mat and on the inclination plank was taken. Since it is assumed that the other conditions score maximally in a healthy population. It's possible that with the naked eye, not all displacements can be seen. In addition to using a clinical test battery, it is also possible to use a romberg ratio coefficient to display change in centre of pressure (COP) for comparing postural sway in eyes open (EO) and eyes closed (EC) conditions. The outcome of this test is presented in the romberg ratio coefficient (COP EC/COP EO). For measuring this, all items of the fifth part of the Kids-BESTest would be taken on a force platform. (Tjernström, Björklund & Malmström, 2015)

Lastly, in domain six (stability in gait) no significant correlation was found with proprioception. Here, the feedforward model is needed as well as previously in domain three. Therefore, it is unexpected that there is a correlation between domain three and not in domain six found since during gait the anticipatory postural control is also needed.

4.2 Reflection on the strengths and weaknesses of the study

4.2.1. Limitations of the study

There are several limitations in this study. A first important limitation is in the protocol of JPS. There was no randomisation but a fixed sequence in the examination of proprioception. For example, this protocol always begins by performing the JPR test at the ankle joint prior to the hip joint. The attention of the child can decrease as the measurement progresses, that's why the test of the hip can be less accurate than the JPR test of the ankle. Ideally, this would also have been randomised, but this was not feasible for practical reasons because of the starting position. Furthermore, proprioception was measured with '3D Vicon motion capturing system' which is rather analytical. Therefore, the children should have a good cognitive function to understand the task. The exact cognitive abilities of the participants was not investigated in this research. This is because we only included children who are going to a typical school and therefore assumed their IQ would be above 70. Another important factor is the participants attention span, participants are sometimes distracted during the performance of the Kids-BESTest and JPR test. Previous studies have shown a clear link between the influence of concentration on both balance and sensory perception (Shum & Pang, 2009; Kamath, Dahm, Tucker, Huang-Pollock, Etter & Neely, 2020). Therefore it can be indirectly assumed that attention will also influence proprioception. During the examination this exact problem also became clear. That's why the balance test of participant fourteen was interrupted due to a fluctuating attention span. Because of this, the participant did not perform according to his/her capabilities, making the results no longer reliable. In the scoring sheet of the Kids-BESTest you can indicate if the child's attention was not good, but it will not be counted any further in the results. Further, the balance results of participant fourteen were not included in the correlation analysis between proprioception and balance and between the correlation of balance and age. However, this is not necessarily negative since participant fourteen is related to participant one. Hereby there are no dependent variables included in these results.

Further, there is one participant who is diagnosed with ASD. During the test, a big difference was noticed between how his muscles relaxed. Some children reacted very strongly by skin contact, which could possibly be explained by their high sensitivity in ASD (Posar & Visconti, 2018; Tomchek & Dunn, 2007; Brockevelt, Nissen, Schweinle, Kurtz & Larson, 2013). This could have a negative effect on the accuracy of the proprioception measurements.

Furthermore there is little research that looks into the differences between both sexes in proprioceptive performances. But recent research shows that there is a difference between the different sexes when it comes to the development of proprioception in the lower limb. Girls showed a lower JRE than boys in both internal and external rotations (Jiang et al., 2018; Muaidi & Q. I. (2017); Hu, Li & Wang (2020); Lee, Ren, Kang, Geiger & Zhang (2014); Herter et al., 2014). Moreover, girls demonstrate more mature balance strategies at earlier ages than boys (Kolic, O'Brien, Bowles, Iles & Williams, (2020); Jiang et al., 2018). Therefore sex should be an factor to take into consideration when performing these tests. In this research, sex differences were not taken into account.

Furthermore, the question can be asked whether the included children are really typically developing. There was no testing previous of the inclusion to establish whether or not their motor performance is according to the norms of a TD Children. It was assumed that all included children had normal motor development if there were no pathologic diagnosis, the child goes to a normal school and the parents did not mention any problems in their motor skills. The fact that they meet all these inclusion and exclusion criteria does not mean that their motor function is fully developed as expected.

4.2.2. Strengths of this study

Firstly, the protocol of both proprioception and balance is that each child is examined by the same person which makes the protocol more standardised. The Kids-BESTest protocol is administered to each child in a different randomised order which is based on randomization with sealed envelopes. This is done because children have difficulty maintaining concentration during the entire test, which would result in the same last item scoring poorly.

The methods used to assess proprioception in prior studies were mostly clinically based and limited to goniometric assessments of joint angles which is less reliable compared to three dimensional (3D) motion analysis (Deng, & Shih, 2015) which was used in this pilot-study. Here, proprioception was measured with '3D Vicon motion capturing system' which is considered as the gold standard which measures all joint angles very precisely. The markers were always placed by the same person. Further, clinicians currently use mostly indirect assessments that provide a method of screening, where the follow-up is done with clinical observations. These indirect assessments are usually through parents' reports or clinician observation checklists such as the Sensory Profile, The Sensory Processing Measure and The Comprehensive Observation of Proprioception. Whereas direct proprioceptive assessments allow more accurate evaluations. Several direct assessments for proprioception are the Sensory Integration and Praxis Test, the Kinesthetic Sensitivity Test and Joint position matching (Chu, 2016).

Because of the small sample size, the Pearson Correlation Coefficient was used. With the Pearson correlation coefficient (r), one can only see whether there is a correlation present, but not whether there is an interaction effect. With a Pearson analysis it is not possible to include secondary factors, such as age, in the analysis. Linear regression can be used to calculate this more accurately, if the sample size is sufficient.

4.3 Recommendations for further research

As previously mentioned, sustained attention is an important factor in both proprioception and balance (Shum et al., 2009; Kamath et al., 2020). It takes a lot of attention to make an accurate estimation of the reference joint angle, not only sustained attention is needed but also working memory. Further, attention is needed to obtain and maintain your balance throughout movements. Because of this it can be recommended to further research to exclude attention disorders such as Attention Deficit Hyperactivity Disorder (ADHD) with the testing of the participating children.

Another population that should be considered as an exclusion of the typically developing test group are children diagnosed with ASD. Because ASD is linked with high sensitivity (Posar et al., 2018; Tomchek et al., 2007; Brockevelt et al., 2013) which could influence the findings. If you would not exclude them you potentially measure their sensitivity problems more than proprioception. Which in turn gives a distorted picture of the development and possibilities of a TD Children. To make sure this problem won't arise in the following research it is recommended to ask the parents to fill in a concentration questionnaire such as the ‘Child Behaviour Checklist-Attention Problem scale’ and ‘Conners Rating Scale-Revised’ about their child (Chang, Wang & Tsai, 2016).

Furthermore, there could also be differences in motor development. These differences are not always clear, that’s why in further research it’s necessary for adding a clinical test (i.e. Movement Assessment Battery for Children) to check whether a child develops according to his or her age. Next to delay in motor development, sport activities can also provide better motor performance.

Since the Kids-BESTest is a clinical test battery we suggest adding more neuro biomechanical measurements as well such as EMG, VICON and force platform to know the values of COP. When you add these different tests, there will be a more clear view obtained of all aspects of balance performance.

For further research, a larger sample size is recommended. Thereby, there is the possibility to apply linear regression, through which not only the correlation but also the interaction between proprioception and balance can be calculated. The advantage of linear regression is that we can add values, such as age, by applying multiple regression.

Furthermore, it is advisable to measure proprioception two different times, with at least four weeks apart recommended by the Cosmin guidelines to assess the reliability of the used examination. With repeating the protocol, the minimal detectable change of the JRE could be calculated and potentially a minimal clinically important difference can be drawn up.

When further research finds a significant correlation between balance and proprioception it will impact the treatment of balance deficits. Proprioception would get a more pronounced role in the therapy concerning balance.

Conclusion

In this study a significant correlation was found between age with proprioception and age with anticipatory balance performance. Both proprioception and anticipatory balance performance increased with age. The correlation between proprioception and balance performance was found not significant except in domain three 'Transitions and anticipatory postural adjustments' of the Kids-BESTest. Therefore, it is unclear whether proprioception correlates with all balance domains. Further large-scale research is needed for a more comprehensive analysis about this topic and to check if there is an interaction effect from proprioception on balance performance.

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Attachments

INVENTARISATIEFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
6/10/2021	Mailconversatie Nina Jacobs en Pieter Meyns: • Bespreking opstarten MP2, testdata kinderen en voorbereiding op testafnames	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
20/10/2021	Online meeting met Nina Jacobs: • Bespreken aanpak MP2, data verzamelen kinderen voor testafnames	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
25/10/2021	Mail naar Nina jacobs: • Opgestelde deadlines doorgestuurd	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
14/11/2021	Mail van Nina Jacobs: • Uitleg mogelijke datacollectie	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
17/11/2022	Mail van Nina: • Feedback op deadlines	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien

13/11 -22/11	Mailconversatie Nina Jacobs: • Eerste draft introductie (oude onderwerp) afgeleverd + informatie ontvangen omtrent gebruikte methode	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
12/12 -16/12	Mailconversatie Nina Jacobs: • Eerste draft methode (oude onderwerp) afgeleverd + ontvangen feedback eerste draft methode en inleiding	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
26/12/2021	Mailconversatie Nina Jacobs en Pieter Meyns: • Doorsturen 2de draft inleiding en methode	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
7/2/2022 - 8/2/2022	Mailconversatie Nina Jacobs : • Afspraak volgende online meeting 14/02	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
14/02/2022	Online meeting met Nina Jacobs: • Verloop recrutering, data-extractie en verwerking bespreken	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
01/03/2022	Mailconversatie Nina Jacobs: • Afspraak meeting Nina Jacobs en Pieter Meyns + info over recrutering typisch ontwikkelende kinderen, inplannen mogelijk	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien

01/03/2022 - 11/06/2022	Conversaties met Nina Jacobs via mail/telefonisch/whatsapp: • Inplannen metingen + assisteren bij metingen	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
08/03/2022	Online meeting Nina Jacobs en Pieter Meyns: • Verandering doelgroep masterproef	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
20/03/2022	Mail naar Nina Jacobs: • Aanpassing deadlines, meer zicht op planning van de testmetingen	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
22/03/2022	Mail van Nina Jacobs: • Feedback op 2e draft inleiding en methode (oude onderwerp)	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
31/03/2022	Mail van Evi Verbecque: • Info omtrent afname Kids-Bestest, en opleiding hiervoor	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien

03/04/2022	Mail naar Nina Jacobs: • Aanpassen deadlines, doordat er nog geen data beschikbaar was + eerste draft inleiding en methode nieuw onderwerp	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
12/04/2022	Mail naar Nina Jacobs: • Draft 1 voorstel statistiek	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
21/04/2022	Meeting Evi Verbecque : • Scoring Kids-Bestest	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
22/04/2022	Mail van Evi Verbecque: • Scoringscriteria ontvangen	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
26/04/2022	Mail naar Nina Jacobs: • Cursus Kids-Bestest afgerond	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
27/04/2022	Mail van Nina Jacobs: • Resultaten meting Kids-Bestest ontvangen via drive	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien

08/05/2022	Mail naar Nina Jacobs: • Aangepaste deadlines + vastleggen nieuwe online meeting	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
10/05/2022	Mail van Nina Jacobs: • Resultaten meting Proprioceptie ontvangen via drive	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
14/05/2022	Online meeting met Nina Jacobs: • Bespreking voorstel statistiek	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
16/05/2022	Mail naar Nina Jacobs: • Eerste draft resultaten	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
21/05/2022	Mondeling feedback discussie: • Startpunt gegeven discussie aan Lien Verecken	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien

24/05/2022	Mail naar Nina Jacobs en Pieter Meyns: • Volledige eerste versie masterproef verstuurd met vraag ter goedkeuring voor verdediging	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
25/06/2022	Mail van Pieter Meyns: • Goedkeuring Masterproef	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
31/05/2022	Mail van Nina Jacobs: • Feedback op resultaten	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
01/06/2022	Mail van Nina Jacobs: • Feedback op discussie, afspraak voor online meeting om verder te bespreken	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
02/06/2022	Online meeting met Nina Jacobs: • Feedback discussie	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien
02/06/2022	Mail van Pieter Meyns: • Feedback eerste draft masterproef	Promotor: Copromotor/Begeleider: Student(e): Lauwers Kaat Student(e): Verecken Lien

In te vullen door de promotor(en) en eventuele copromotor aan het einde van MP2:

1. Geef aan in hoeverre de student(e) onderstaande competenties zelfstandig uitvoerde:
    - NVT: De student(e) leverde hierin geen bijdrage, aangezien hij/zij in een reeds lopende studie meewerkte.
    - 1: De student(e) was niet zelfstandig en sterk afhankelijk van medestudent(e) of promotor en teamleden bij de uitwerking en uitvoering.
    - 2: De student(e) had veel hulp en ondersteuning nodig bij de uitwerking en uitvoering.
    - 3: De student(e) was redelijk zelfstandig bij de uitwerking en uitvoering
    - 4: De student(e) had weinig tot geringe hulp nodig bij de uitwerking en uitvoering.
    - 5: De student(e) werkte zeer zelfstandig en had slechts zeer sporadisch hulp en bijsturing nodig van de promotor of zijn team bij de uitwerking en uitvoering.

Competenties	**NVT**	**1**	**2**	**3**	**4**	**5**
Opstelling onderzoeksvraag	O	O	O	O	O	O
Methodologische uitwerking	O	O	O	O	O	O
Data acquisitie	O	O	O	O	O	O
Data management	O	O	O	O	O	O
Dataverwerking/Statistiek	O	O	O	O	O	O
Rapportage	O	O	O	O	O	O

2. Niet-bindend advies: Student(e) krijgt toelating/geen toelating (schrappen wat niet past) om bovenvermelde Wetenschappelijke stage/masterproef deel 2 te verdedigen in bovenvermelde periode. Deze eventuele toelating houdt geen garantie in dat de student geslaagd is voor dit opleidingsonderdeel.

3. Deze wetenschappelijke stage/masterproef deel 2 mag wel/niet (schrappen wat niet past) openbaar verdedigd worden.

4. Deze wetenschappelijke stage/masterproef deel 2 mag wel/niet (schrappen wat niet past) opgenomen worden in de bibliotheek en docserver van de UHasselt.

Datum en handtekening Student(e)	Datum en handtekening promotor(en)	Datum en handtekening Co-promotor(en)

Inschrijvingsformulier verdediging masterproef academiejaar 2021-2022,

Registration form jury Master's thesis academic year 2021-2022,

GEGEVENS STUDENT - *INFORMATION STUDENT*

Faculteit/School: **Faculteit Revalidatiewetenschappen**
Faculty/School: ***Rehabilitation Sciences***

Stamnummer + naam: **1746067 Verecken Lien**
Student number + name 1541542 Lauwers Kaat

Opleiding/*Programme*: **2 ma revalid. & kine kinderen**

INSTRUCTIES - *INSTRUCTIONS*

Neem onderstaande informatie grondig door.

Print dit document en vul het aan met DRUKLETTERS.

In tijden van van online onderwijs door COVID-19 verstuur je het document (scan of leesbare foto) ingevuld via mail naar je promotor. Je promotor bezorgt het aan de juiste dienst voor verdere afhandeling.

Vul luik A aan. Bezorg het formulier aan je promotoren voor de aanvullingen in luik B. Zorg dat het formulier ondertekend en gedateerd wordt door jezelf en je promotoren in luik D en dien het in bij de juiste dienst volgens de afspraken in jouw opleiding.
Zonder dit inschrijvingsformulier krijg je geen toegang tot upload/verdediging van je masterproef.

Please read the information below carefully.

Print this document and complete it by hand writing, using CAPITAL LETTERS.

In times of COVID-19 and during the online courses you send the document (scan or readable photo) by email to your supervisor. Your supervisor delivers the document to the appropriate department.

Fill out part A. Send the form to your supervisors for the additions in part B. Make sure that the form is signed and dated by yourself and your supervisors in part D and submit it to the appropriate department in accordance with the agreements in your study programme.
Without this registration form, you will not have access to the upload/defense of your master's thesis.

LUIK A - VERPLICHT - IN TE VULLEN DOOR DE STUDENT
PART A - MANDATORY - TO BE FILLED* OUT *BY THE STUDENT

Titel van Masterproef/*Title of Master's thesis:*

O behouden - *keep*

◆ wijzigen - *change to*:
Proprioception in school-aged typical developing children: ankle and hip proprioception and the correlation with balance performance

O behouden - *keep*

O wijzigen *- change to*:

In geval van samenwerking tussen studenten, naam van de medestudent(en)/*In case of group work, name of fellow student(s)*:

◆ behouden - *keep*

O wijzigen *- change to:*

LUIK B - VERPLICHT - IN TE VULLEN DOOR DE PROMOTOR(EN)
PART B - MANDATORY - TO BE FILLED OUT BY THE SUPERVISOR(S)

Wijziging gegevens masterproef in luik A/*Change information Master's thesis in part A:*

◆ goedgekeurd - *approved*

O goedgekeurd mits wijziging van - *approved if modification of:*

Scriptie/*Thesis:*

◆ openbaar (beschikbaar in de document server van de universiteit)- *public (available in document serverof university)*

O vertrouwelijk (niet beschikbaar in de document server van de universiteit) - *confidential (not available indocument server of university)*

Juryverdediging/*Jury Defense:*

De promotor(en) geeft (geven) de student(en) het niet-bindend advies om de bovenvermelde masterproef in de bovenvermelde periode/*The supervisor(s) give(s) the student(s) the non-binding advice:*

◆ te verdedigen/*to defend the aforementioned Master's thesis within the aforementioned period of time*

◆ de verdediging is openbaar/*in public*

O de verdediging is niet openbaar/*not in public*

O niet te verdedigen/*not to defend the aforementioned Master's thesis within the aforementioned period of time*

LUIK C - OPTIONEEL - IN TE VULLEN DOOR STUDENT, alleen als hij luik B wil overrulen
PART C - OPTIONAL - TO BE FILLED OUT BY THE STUDENT, only if he wants to overrule part B

In tegenstelling tot het niet-bindend advies van de promotor(en) wenst de student de bovenvermelde masterproef in de bovenvermelde periode/*In contrast to the non-binding advice put forward by the supervisor(s), the student wishes:*

O niet te verdedigen/*not to defend the aforementioned Master's thesis within the aforementioned period of time*

O te verdedigen/*to defend the aforementioned Master's thesis within the aforementioned period of time*

LUIK D - VERPLICHT - IN TE VULLEN DOOR DE STUDENT EN DE PROMOTOR(EN) ***PART D - MANDATORY - TO BE FILLED OUT BY THE STUDENT AND THE SUPERVISOR(S)***

Datum en handtekening student(en) *Date and signature student(s)*

30/05/2022

Lauwers Kaat   Verecken Lien

Datum en handtekening promotor(en)
Date and

signature

supervisor(s)

Promotor: Prof. Dr. Meyns Pieter   Begeleidster: Mevr. Jacobs Nina

25/5/2022