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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Proprioceptive weighting during postural control in pregnant and non-pregnant women

Laura Jochmans

Frauke Vercalsteren

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

PROMOTOR :
Prof. dr. Lotte JANSSENS

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The past two years we have been supported by several people to arrive at what we now call our master's thesis. Therefore, we would like to thank all these individuals for their help, support, and commitment.

First of all, we would like to thank Prof. Dr. L. Janssens, Dr. N. Goossens, Prof. Dr. K. Bogaerts and Dra. C. Amerijckx for guiding us with their advice during these two years. They have always provided us with expert advice and valuable feedback. Furthermore, we also appreciate the chances that our university, UHasselt, gave us to set up the experiments in the REVAL Rehabilitation Research Center (UHasselt, Diepenbeek). We would also like to thank our participants for participating and being available for our master's thesis.

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Research context

This master thesis is part of the musculoskeletal rehabilitation research domain. One of the focuses of this research group is to identify multidimensional mechanisms that contribute to musculoskeletal complaints in order to find appropriate physiotherapeutic treatments for these patients. More specifically, this master thesis concentrates on the difference of proprioceptive weighting during postural control between pregnant women in their first trimester, pregnant women in their third trimester, and non-pregnant women.

Pregnant women can develop pregnancy-related lumbopelvic pain (PLPP), which involves pelvic girdle pain, low back pain (LBP), or both. Recent studies show that up to 77% of pregnant women suffer from PLPP during their pregnancy (Bergström et al., 2014). To date, research has focused primarily on motor output, such as abdominal muscle weakness and increased lumbar lordosis. The role of sensory input, and especially proprioception, both crucial for optimal motor output has not yet been investigated. Nevertheless, lumbar proprioceptive dysfunction and impaired body perception have already been shown to contribute to back pain in the general population (Pickar et al., 2013; Cholewicki et al., 2005). Therefore, the aim of this study was to investigate the differences in sensory factors in pregnant women in the first and third trimester of pregnancy and in non-pregnant women as a control group.

This master thesis is part of a postdoctoral project of Dr. N. Goossens named: "Improving maternal health by identifying and tackling predictive factors for the development of low back pain during pregnancy and postpartum", funded by Co-financiering AXA Research Fund. Therefore, the research method and protocol were provided by Prof. Dr. Lotte Janssens and Dr. Nina Goossens.

Recruitment of the pregnant participants had already been carried out. The non-pregnant participants were recruited in collaboration with another master's thesis duo who included the same participants.

The tests were conducted by Dr. N. Goossens with the assistance of one student, and took place in the REVAL Rehabilitation Research Center (UHasselt, Diepenbeek). Dr. N. Goossens processed the data, and it was delivered to the students in an excel file with all the outcome measures for each duo.

Data processing was performed by the students themselves, this by using JMP software. The description of the results and other parts of the master's thesis was performed by both students with feedback and declarations of prof. dr. Janssens and dr. Goossens.

Bergström, C., Persson, M., & Mogren, I. (2014). Pregnancy-related low back pain and pelvic girdle pain approximately 14 months after pregnancy–pain status, self-rated health and family situation. *BMC pregnancy and childbirth*, *14*(1), 1-12.

Cholewicki, J., Silfies, S. P., Shah, R. A., Greene, H. S., Reeves, N. P., Alvi, K., & Goldberg, B. (2005). Delayed trunk muscle reflex responses increase the risk of low back injuries. Spine, 30(23), 2614-2620.

Pickar, J. G. (2013). Proprioceptive contributions from paraspinal muscle spindles to the relationship between control of the trunk and back pain. In Spinal Control (pp. 145-155). Churchill Livingstone.

Table of content

1. Abstract

Background: As result of anatomical and physiological changes occurring during pregnancy, there is anterior-superior displacement of the center of gravity, which impacts postural control. However, the role of proprioceptive weighting that interacts with postural control in pregnant women is not known.

Objectives: The aim of this study was to investigate the difference of proprioceptive weighting during postural control between pregnant women in their first trimester, third trimester, and non-pregnant women.

Participants: 13 pregnant- and 20 non-pregnant women participated. They were aged 18-40 years old, pregnant women had a singleton pregnancy, and were multiparous.

Measurements: Proprioceptive use during postural control was measured during upright standing in four different trials with vision occluded, stable- and unstable support surfaces and vibration of ankle- and back muscles. Center of pressure (COP)-displacements in response to this vibration, and the Relative Proprioceptive Weighting (RPW) ratio were calculated. Statistical analysis was performed with JMP pro 16.1, and level of significance was set at $p<0.05$.

Results: A significantly greater COP displacement was found in pregnant women in their first trimester compared to their third trimester ($F=8.62$; $p=0.03$), and to non-pregnant women ($F=8.89$; $p=0.006$) during ankle muscle vibration, independent of the support surfaces. Compared to non-pregnant women (RPW = 59.91%), pregnant women in their third trimester showed a more ankle-steered strategy on an unstable support surface (RPW= 65.23%).

Conclusion: Pregnant women in their first trimester showed more reliance on ankle muscle proprioception compared to non-pregnant women, independent of the support surface. This was also seen in their first- and third trimester of pregnancy compared to non-pregnant women. In their third trimester of pregnancy, women showed a more ankle steered strategy on an unstable support surface. Biomechanical changes throughout pregnancy might influence proprioceptive weighting, but its exact role needs further investigation.

Keywords: Pregnancy, proprioceptive weighting, proprioception, postural control, vibration

2. Introduction

Pregnant women can develop pregnancy-related lumbopelvic pain (PLPP), which involves pelvic girdle pain, low back pain (LBP), or both. Recent studies show that up to 77% of pregnant women suffer from PLPP during their pregnancy (Bergström et al., 2014). They usually start to have PLPP at 18 weeks of pregnancy, with a peak between 24- and 36-weeks postmenstrual age (Wu et al., 2004; Gutke et al., 2006). Most women recover within three months of delivery, but 5% do not (Bergström et al., 2014; Wu et al., 2004; Gutke et al., 2006). Moreover, if a woman has suffered from PLPP in the past, this condition will probably return during subsequent pregnancies (Larsen et al., 1999; Albert et al., 2002; Albert et al., 2006; Wu et al., 2004; Bastiaanssen et al., 2005; Mogren et al., 2005).

Several physiological changes affect the musculoskeletal system during pregnancy. This is expressed in terms of gaining weight, increased joint laxity, forward pelvic rotation, and vascular changes. Compensations for these changes include an accentuated lower back curvature, anterior pelvic tilting, and a hyperextension of the upper back (Casagrande et al., 2015). As a result of the anatomical and physiological changes that occur during pregnancy, there is a displacement of the center of gravity to anterior-superior, which has an impact on postural control (Cakmak et al., 2016; Casagrande et al., 2015). Evidence shows that pregnant women have an increased COP path length and COP sway excursion during their second and third trimester compared to non-pregnant individuals (Butler et al., 2006; Karadag-Saygi et al., 2010). The study of Opala-Berdzik et al. (2015) confirms this finding of an affected postural stability in pregnant women, expressed by an increased anterior-posterior COP path length and COP velocity in their late pregnancy (36 weeks) in comparison to non-pregnant individuals. These changes are commonly found in the third semester, because of greater body weight influencing the biomechanics of the body, and thereby postural control (Conder et al., 2019). However, Danna-Dos-Santos et al. (2018) also found significantly increased body sway area and range in the first trimester of pregnancy, suggesting that each pregnant woman has an individual morphology with varying effects on their biomechanics (Conder et al., 2019).

Postural control is achieved by the integration of vestibular, visual, and proprioceptive sensory information in the central nervous system (CNS) (Sorensen et al., 2002). Based on the specific situation, vestibular, visual, and proprioceptive inputs are weighted, and the focus will be on the most reliable sensory inputs (Carver et al., 2006). For example, when an individual stands on an unstable support surface, ankle muscle proprioception will be less reliable and the reliance of the CNS on visual and vestibular inputs will be increased (Ivanenko et al., 1999). Butler et al. (2006) demonstrated the influence of altered visual inputs on postural control changes in pregnant women, presented by an increased path length and average radial displacement of the center of pressure (COP) during eyes closed compared to non-pregnant women. Moreover, this difference in path length and average radial displacement while standing with eyes open compared to eyes closed also increased during pregnancy, implicating a greater reliance on visual inputs throughout pregnancy (Butler et al., 2006). The underlying mechanisms of these altered postural control outcomes in pregnant women are not really known (Cakmak et al., 2016). However, a possible explanation can be a disturbed proprioceptive use, since muscle activation of lumbar paraspinal and triceps surae muscles, potentially affected by pregnancy, play a key role in the control of postural tasks (Hungerford et al., 2003). This is expressed by a multisegmental- and ankle-steered postural control strategy, respectively (Claeys et al., 2011; Brumagne et al., 2008; Horak et al., 1986).

The relative contribution of the proprioceptive afferents from respectively the multifidus and triceps surae muscles to postural control can be determined by applying local muscle vibration to these muscles (Brumagne et al., 2008; Pijnenburg et al., 2014). In the CNS, muscle vibration is interpreted as an elongation of the muscles, which leads to an illusion in the change of the actual joint position (Cordo et al., 2005; Goodwin et al., 1972; Roll et al., 1982). As a consequence, individuals will displace their center of mass in opposite directions to prevent falling in case they make use of these particular proprioceptive afferents of the vibrated muscles (Brumagne et al., 2008). According to Brumagne et al. (2004), and Claeys et al. (2011), the relative proprioceptive weighting ratio of the postural response to ankle vs. back muscle vibration is decreased in LBP patients compared to healthy individuals, indicating a more dominant reliance on ankle muscle proprioception in LBP patients. However, the role of proprioceptive weighting of multifidus and triceps surae muscles in pregnant women that interacts with this postural control is not known (Bloem et al., 2000; Sorensen et al., 2002). It is expected that a similar pattern as in LBP patients will be seen in pregnant women, since they are often subject to PLPP during their pregnancy (Bergström et al., 2014).

There is clearly insufficient evidence to draw conclusions regarding the proprioceptive weighting during postural control in pregnant women, and to what extent this is comparable to non-pregnant individuals. Therefore, the aim of this study was to investigate if there is a difference of proprioceptive weighting during postural control between pregnant women in their first trimester, pregnant women in their third trimester, and non-pregnant women.

3. Method

3.1. Research questions and hypothesis

3.1.1. Research questions

- Is there a difference of proprioceptive weighting during postural control between pregnant women in their first trimester and third trimester?
- Is there a difference of proprioceptive weighting during postural control between pregnant women in their first trimester and non-pregnant individuals?
- Is there a difference of proprioceptive weighting during postural control between pregnant women in their third trimester and to non-pregnant individuals?

3.1.2. Hypothesis

We expected that pregnant women in their third trimester compared to their first trimester will show an ankle steered postural control strategy, assuming that the reliance on proprioceptive inputs is greater in the triceps surae than in the multifidus muscles.

This tendency would also be seen in women in their first and third trimester of pregnancy, compared to non-pregnant individuals. However, we expect these changes will be less pronounced in the first trimester of pregnancy, compared to non-pregnant women.

3.2. Study design

A longitudinal study design was used to compare pregnant women in their first trimester to their third trimester.

A cross-sectional study design was used to compare pregnant women in their first and third trimester to non-pregnant individuals.

3.3. Participants

3.3.1. Inclusion criteria

The following inclusion criteria were used for the pregnant women: (1) aged between 18-40 years old; (2) singleton pregnancy; (3) pregnant of (more than) second child (4) score ≤ 2% on the Modified Low Back Pain Disability Questionnaire (MDQ) (indicating no disability due to LBP/PPGP); and (5) willing to sign informed consent form.

For the non-pregnant individuals, the following inclusion criteria were applied: (1) women; (2) between 18 and 40 years old; (3) not currently pregnant and never been pregnant before; (4) BMI <30 kg/m²; (5) willing to sign informed consent form.

3.3.2. Exclusion criteria

The following exclusion criteria were used for the pregnant women: (1) pregnant for more than 14 weeks; (2) having current PPGP or having had PPGP during the current pregnancy with a score > 2% on the MDQ, (3) history of surgery/major trauma to spine, pelvis and/or lower limbs; (4) specific balance or vestibular disorders; (5) spinal deformities; (6) rheumatic disease; (7) neurological abnormalities (e.g., peripheral neuropathy); (8) uncorrected visual problems; (9) hyperemesis gravidarum; (10) acute ankle problems; (11) pre-existing disorders that could interfere with the course of pregnancy (e.g., hypertension, kidney disease, coagulation disorders); (12) (a history of) psychiatric disorders; (13) and non-Dutch speaking.

For the non-pregnant individuals, the following exclusion criteria were applied : (1) LBP or pelvic girdle pain currently or in the past six months; (2) chronic low back or pelvic girdle pain in history; (3) surgical procedure or major trauma to spine, pelvis, or lower extremities in history; (4) specific vestibular or balance disorder; (5) spinal deformity (e.g., structural, uncorrectable scoliosis); (6) rheumatic disease; (7) neurological abnormality (e.g., peripheral neuropathy, epilepsy); (8) uncorrected vision problems (e.g., severe far or nearsightedness not corrected with glasses or lenses); (9) acute ankle problem (e.g., ankle sprain less than 3 weeks ago); (10) psychiatric disorder (or history of a psychiatric disorder); (11) non-Dutch speaking.

3.4. Recruitment

13 multiparous women were recruited in their first (T1) trimester of pregnancy and were tested in their first and third (T3) trimester of pregnancy. Likewise, 20 non-pregnant individuals were recruited. They all visited the REVAL Rehabilitation Research Center of UHasselt in Diepenbeek for testing. Data from COP measurements were missing in five pregnant women in their first trimester and one pregnant woman in her third trimester.

3.5. Baseline characteristics

Participants were asked about demographic and anthropometric data: age, height, current weight, pre-pregnancy weight (table 1).

Table 1
Participants' characteristics.

	Pregnant women, T1 (n = 8)	Pregnant women, T3 (n = 12)	Non-pregnant individuals (n = 20)
Age (yrs)	31 ± 2.5	30 [29-34]	28 [26-30]
Height (m)	1.68 ± 0.06	1.67 ± 0.06	1.67 ± 0.08
Current Weight (kg)	71.4 ± 10.4	80.2 ± 11.9	62 [56.4-65]
Pre-pregnancy weight (kg)	69.7 ± 10.4	68.5 ± 10.5	62 [56.4-65]
Current BMI (kg/m²)	25.4 ± 3.8	28.66 ± 4.0	22.39 ± 1.7
Pre-pregnancy BMI (kg/m²)	24.8 ± 3.7	24.5 ± 3.6	22.3 ± 1.7

The values are means with standard deviations if data was normally distributed. If not, the values are median with interquartile distance; BMI: Body mass index.

3.6. Medical ethics

This study was approved by the Medical Ethics Committee of the Ziekenhuis Oost-Limburg, and additionally by the UHasselt, Jessa Ziekenhuis, Sint-Franciscus Ziekenhuis, Ziekenhuis Maas en Kempen, Mariaziekenhuis Noord-Limburg, and Algemeen Ziekenhuis Vesalius as local committees (B371201942396).

3.7. Measurement

3.7.1. Study procedure

The study procedure was applicable to the pregnant group and the non-pregnant group.

First, personal information (maternal age, number of pregnancies, child deliveries and miscarriages, marital status, annual household income, educational level, current profession, job status, smoking habits, alcohol and drug consumption, history of low back pain, physical activity, subjective sleep), demographic (age) and anthropometric data (height, current weight, pre-pregnancy weight, current BMI, pre-pregnancy BMI) were collected.

Afterwards the proprioceptive use during postural control was measured during upright standing in four different trials with vision occluded, different support surfaces (stable/unstable) and vibration of different muscles (ankle muscles/back muscles) as described in table 2 (Claeys et al., 2011; Claeys et al., 2012; Claeys et al., 2015; Janssens et al., 2016; Ivanenko et al., 1999: Brumagne et al., 2008; Brumagne et al., 2004; Goossens et al., 2019).

Table 2
Overview of trials to assess proprioceptive use during postural control

Trial	Condition
1	Stable support surface, vibration of ankle muscles, vision occluded
2	Stable support surface, vibration of back muscles, vision occluded
3	Unstable support surface, vibration of ankle muscles, vision occluded
4	Unstable support surface, vibration of back muscles, vision occluded

(Claeys et al., 2011; Claeys et al., 2012; Claeys et al., 2015; Janssens et al., 2016; Ivanenko et al., 1999; Brumagne et al., 2008; Brumagne et al., 2004; Goossens et al., 2019).

3.7.2. Test setting and standardization

The selection of materials and procedures was based on earlier research (Brumagne et al., 2004; Brumagne et al., 2008; Claeys et al., 2011; Kiers et al., 2014; Pijnenbrug et al., 2014). For each trial, the participants were asked to stand barefoot on the six-channel force plate (AMTI, USA) and to stand relaxed, while the COP was measured. As an unstable support surface, a foam pad (Airex Balance Pad Elite, Airex Switzerland) was placed on top of the force plate.

After each trial, participants were given a one-minute pause (or longer if required). To standardize the foot position, a transparent sheet was used, on which the foot position was marked (heels 20cm-apart). Participants wore non-transparent glasses to occlude vision but were asked to keep their eyes open.

When ankle muscle vibration was used, two muscle vibrators (Maxon Motors, Switzerland, 60 Hz, 0.5 mm) were placed bilaterally over the triceps surae (further called as 'ankle muscles'). When lumbar muscle vibration was applied, one vibrator (Maxon Motors, Switzerland, 60 Hz, 0.5 mm) was attached over the lumbar paraspinal muscles (further called as 'back muscles'). (fig. 1).

For safety during the test, all participants wore a safety harness, and an assistant was standing close to the participant, this was different from the other studies.

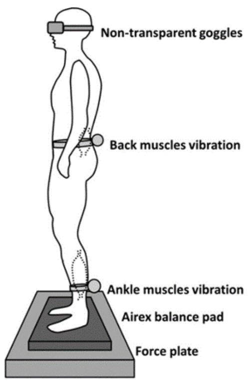

Fig. 1. Test setting (Janssens et al., 2016)

3.7.3. Trials

All participants underwent four trials with different conditions to investigate proprioceptive use during postural control, represented in Table 2. All trials were performed in upright standing. In trial 1 and 3, there was vibration of the triceps surae (ankle muscles) and in trial 2 and 4, there was vibration of the lumbar paraspinal muscles (back muscles). All trials were with vision occluded. Each trial lasted for 60 seconds. The muscle vibration was initiated 15 seconds after the start and applied for 15 seconds. When the vibration ended, the person was asked to continue standing for another 30 seconds (Claeys et al., 2011; Claeys et al., 2012; Claeys et al., 2015; Janssens et al., 2016; Ivanenko et al., 1999: Brumagne et al., 2008; Brumagne et al., 2004; Goossens et al., 2019).

3.8. Outcome measures

Center of pressure (COP) was measured by a force plate with a sampling frequency of 1000 Hz. The signals were then smoothed by use of a low-pass 4th order Butterworth filter with a cut-off frequency of 6 Hz.

As primary outcome measurements, mean COP-displacements in response to ankle muscle vibration and back muscle vibration, and subsequently the Relative Proprioceptive Weighting (RPW) ratio were calculated.

From the raw force plate data an estimation was made for mean COP displacement in anterior-posterior direction during muscle vibration with the formula: COP = Mx/Fz (Brumagne et al., 2008; Brumagne., 2004; Goossens et al., 2019). Positive values indicate a COP displacement in anterior direction (Claeys et al., 2015; Goossens et al., 2019). Negative values represent a COP displacement in posterior direction (Claeys et al., 2015; Goossens et al., 2019). It serves as an indicator for the amount of proprioceptive signals the participant uses to maintain postural balance (Janssens et al., 2016). COP displacement during muscle vibration was calculated by the change in COP position during muscle vibration compared to the previous 15s before vibration was applied (Brumagne et al., 2004; Brumagne et al., 2008; Kiers et al., 2014).

The Relative Proprioceptive Weighting (RPW) ratio is described as the absolute COP displacement during ankle muscle vibration in relation to the absolute COP displacements during ankle and lumbar paraspinal muscle vibration (Brumagne et al., 2008; Goossens et al., 2019). It is calculated by the division of the absolute COP displacement during ankle vibration by the total of the absolute COP displacement during ankle and back vibration (Brumagne et al., 2008). The higher the relative reliance on ankle proprioceptive inputs, the greater the ratio, indicating a more dominant ankle-steered use of ankle muscle proprioception during postural control (Brumagne et al., 2008; Claeys et al., 2011; Kiers et al., 2014).

3.9. Data analysis

3.9.1. Participants' characteristics

Participants' characteristics of all subjects were summarized by testing normality using the Shapiro-Wilk test. If data was normally distributed the values are means with standard deviations (SD), if not the values are median with interquartile distance (IQR). The statistical analysis was performed with JMP pro 16.1. The level of significance was set at $p<0.05$.

Group differences in demographic and anthropometric characteristics between T1 and T3 were made by performing a Wilcoxon signed rank test. This test was chosen because the groups contain dependent subjects and data was not univariate.

Based on assumptions (normality and homoscedasticity), a two-sample-t-test, Wilcoxon rank sum test or Welch's test was used to examine group differences in demographic and anthropometric characteristics between T1/T3 and non-pregnant women. Normal distribution was assessed by Shapiro-Wilk test, and homoscedasticity by Brown-Forsythe test.

3.9.2. Effects of local muscle vibration on COP variables

Differences in COP outcomes between T1 and T3 were determined with a repeated measures ANOVA, with time (T1, T3), and support surface (stable/unstable) as within-subject factor, and subject ID. Group differences between T1/T3 and non-pregnant women were determined by using a mixed model ANOVA. The within-subject factor is support surface (stable/unstable) and the different groups (T1, T3, non-pregnant) were taken as between-subject factors. As a post hoc test a student's t test was performed with significance level <0.05.

4. Results

4.1. Baseline descriptive characteristics

In total, 13 pregnant women and 20 non-pregnant women were included. Participant characteristics are presented in table 3-5. COP data were missing for five pregnant women in their first trimester and one pregnant woman in her third trimester. Therefore, participant characteristics were only presented for women whose COP data were available. Moreover, to evaluate differences in participant characteristics within pregnant women, we only used COP data from the seven women that was collected in both their first and third trimester.

All characteristics of pregnant women were normally distributed. In non-pregnant individuals, age, and weight were not normally distributed.

When comparing changes in participants' characteristics over time, there was a significant difference in weight (p = 0.02) and BMI (p = 0.02) within pregnant women (table 3). Pregnant women in their first trimester were significantly older than non-pregnant women (p = 0.004, table 4). All other characteristics were not significantly different between these two groups. Pregnant women in their third trimester were in general older (p = 0.005), had a higher current weight (p = 0.0003) and a higher current BMI (p = 0.0002) compared to non-pregnant women (table 5).

Table 3
Participants' characteristics first trimester vs third trimester

	Pregnant women, T1 (n = 7)	Pregnant women, T3 (n = 7)	Test statistic	p-value
Age (yrs)	33 [30-36]	34 [30-36]	N/A	N/A
Current weight (kg)	69 [57-74]	76.4 [64-84]	14.00	**0.02**
Current BMI (kg/m²)	23.8 [21.7-27.5]	28.4 [24.4-30.5]	14.00	**0.02**

The values are presented as median [interquartile distance]; A Wilcoxon Signed Rank test and S-value were used; BMI: Body mass index; T1: first trimester; T3; third trimester; N/A: not applicable.

Table 4

Participants' characteristics first trimester vs non-pregnant women

	Pregnant women, T1 (n = 8)	Non-pregnant women (n = 20)	Test statistic	p-value
Age (yrs)	32 [30-35]	28 [26-30]	172	**0.004**[3]
Current weight (kg)	70.3 [58.8-76.3]	62 [56.4-65]	147	0.12[3]
Current BMI (kg/m^2)	24.6 [21.9-27.7]	22.40 [20.99-23.95]	4.56	0.06*

The values are presented as median [interquartile distance]; If data were not normally distributed and variances were equal, a Wilcoxon Rank Sum test ([3]) and S value were used; If variances were not equal, a Welch test (*) and F-ratio were used; BMI: Body mass index; T1: first trimester; **p <0.05** means significant difference.

Table 5

Participants' characteristics third trimester vs non-pregnant women

	Pregnant women, T3 (n = 12)	Non-pregnant women (n = 20)	Test statistic	p-value
Age (yrs)	31 [29-34]	28 [26-30]	271	**0.005**[3]
Current weight (kg)	79.8 [74.5-84.8]	62 [56.4-65]	292	**0.0003**[3]
Current BMI (kg/m^2)	29.1 [24.5-30.6]	22.4 [21-24]	25.59	**0.0002***

The values are presented as median [interquartile distance]; If data were not normally distributed and variances were equal, a Wilcoxon Rank Sum test ([3]) and S value were used; If variances were not equal, a Welch test (*) and F-ratio were used; BMI: Body mass index; T1: first trimester; **p <0.05** means significant difference.

4.2. Effects of local muscle vibration on COP variables

4.2.1. Pregnant women first trimester vs. third trimester

The mean values of COP displacements in response to local muscle vibration and subsequent RPW ratios of the pregnant women in their first and third trimester are listed in table 6.

The results show that there was no significant interaction effect of 'support surface x time' ($F = 2.77$; $p = 0.15$) on COP displacement during ankle muscle vibration. However, a significant main effect of 'support surface' ($F = 12.10$; $p = 0.01$) on COP displacement during ankle muscle vibration was found. Pregnant women seemed to have greater COP displacement during ankle muscle vibration when standing on a stable surface (-1.81 cm) compared to an unstable surface (-1.05 cm), regardless of whether they were in their first or third trimester. A significant main effect of 'time' was also found ($F = 8.62$; $p = 0.03$). Pregnant women showed a greater COP displacement during ankle muscle vibration in their first trimester (-1.86 cm), compared to their third trimester (-0.99 cm), independent from the surface they were standing on.

There was no significant interaction effect of 'support surface x time' ($F = 5.61$; $p = 0.06$) on COP displacement during back muscle vibration. In this condition, there was also no significant main effect of 'support surface' ($F= 0.38$; $p = 0.56$) or 'time' ($F = 0.03$; $p = 0.87$).

Finally, there was no significant interaction effect of 'support surface x time' ($F = 3.98$; $p = 0.09$) on the RPW ratio. There was also no main effect ($F = 2.09$; $p = 0.20$) of 'support surface' or 'time' ($F= 5.56$; $p = 0.06$) on RPW ratio.

Table 6
First trimester vs. third trimester

	T1 (n = 7)	T3 (n= 7)
COP displacement, Ankle, Stable (cm)	-2.45 ± 1.06	-1.17 ± 0.43
COP displacement, Ankle, Unstable (cm)	-1.28 ± 0.55	-0.82 ± 0.40
COP displacement, Back, Stable (cm)	0.26 ± 0.21	0.48 ± 0.19
COP displacement, Back, Unstable (cm)	0.44 ± 0.26	0.18 ± 0.38
RPW (%), Stable	88.22 ± 6.86	70.41 ± 7.74
RPW (%), Unstable	72.40 ± 15.70	69.77 ± 17.41

The values are means with standard deviations if data was normally distributed. RPW: relative proprioceptive weighting; COP: center of pressure.

4.2.2. Pregnant women in their first trimester vs. non-pregnant women

The mean values of RPW ratio and COP displacements during local muscle vibration of the pregnant women in their first trimester and non-pregnant women are listed in table 7.

There was no significant interaction effect of 'support surface x group' (F = 2.59; p = 0.12) on COP displacement during ankle vibration. In this condition, there was a significant main effect of 'group' (F= 8.89; p = 0.006), indicating that pregnant women in their first trimester (-1.93 cm) had a greater COP displacement during ankle muscle vibration than non-pregnant women (-1.22 cm), regardless of the support surface they were standing on. The factor 'support surface' also showed a significant main effect (F = 20.26; p = 0.0001) on COP displacement. Regardless of whether women were pregnant or not, they had a greater COP displacement during ankle muscle vibration when standing on a stable surface (-1.93 cm), compared to an unstable surface (-1.22 cm).

During back muscle vibration, the interaction effect of 'support surface x group' on COP displacement was not significant (F = 1.39; p = 0.25). There was also no significant main effect of 'group' (F = 0.006; p = 0.94) on COP displacement. Nonetheless, the factor 'support surface' did have a significant main effect (F= 26.52; p <0.0001) on COP displacement during back muscle vibration. This demonstrates that, independent from which group women were part of, they all had a greater COP displacement during back muscle vibration when standing on an unstable surface (0.52 cm) compared to a stable surface (0.19 cm).

Finally, the results showed a non-significant interaction effect of 'support surface x group' (F = 0.43; p = 0.43) on the RPW ratio. There was also no significant main effect (F= 3.19; p = 0.09) of 'group' on RPW ratio. The factor 'support surface' had a significant main effect (F = 25.41; p <0.0001) on RPW ratio, independent from the group. This indicates that all women relied more on ankle muscle proprioception and/or relatively less on back muscle proprioception while standing on a stable surface (85,9%) compared to an unstable surface (66,5%).

Table 7
First trimester vs. non-pregnant

	T1 (n= 8)	Non-pregnant (n = 20)
COP displacement, Ankle, Stable (cm)	-2.42 ± 0.99	-1.45 ± 0.69
COP displacement, Ankle, Unstable (cm)	-1.44 ± 0.68	-0.98 ± 0.53
COP displacement, Back, Stable (cm)	0.22 ± 0.22	0.16 ± 0.30
COP displacement, Back, Unstable (cm)	0.47 ± 0.26	0.56 ± 0.34
RPW (%), Stable	89.56 ± 7.40	82.34 ±16.59
RPW (%), Unstable	73.17 ± 14.69	59.91 ± 19.04

The values are means with standard deviations if data was normally distributed. RPW: relative proprioceptive weighting; COP: center of pressure.

4.2.3. Pregnant women in their third trimester vs. non-pregnant women

The mean values of RPW and COP displacements during local muscle vibration of the pregnant women in their third trimester and non-pregnant women are listed in table 8.

There was no significant interaction effect of 'support surface x group' (F = 0.006; p = 0.94) on COP displacement during ankle muscle vibration. The main effect of 'group' on COP displacement was also not significant (F = 0.01; p = 0.90) in this condition. However, there was a significant main effect of 'support surface' (F = 16.29; p = 0.0003), indicating that women showed a greater COP displacement during ankle muscle vibration during standing on a stable surface (-1.43 cm) compared to an unstable surface (-0.98 cm), independent from whether they were pregnant or not.

There was a significant interaction effect of 'support surface x group' (F = 8.16; p = 0.0077) on COP displacement during back muscle vibration. The post-hoc tests in table 9 showed only a significant difference between non-pregnant women in stable or unstable condition (F = 4.20; p = 0.0002). Non-pregnant women had a greater COP displacement during back muscle vibration when standing on an unstable surface (0.56 cm), compared to a stable surface (0.16 cm).

The interaction effect of 'support surface x group' on the RPW ratio was not significant (F = 2.38; p = 0.13). There was also no significant main effect of 'group' (F =0.004; p = 0.95). Finally, there was a significant main effect of 'support surface' (F = 20.92; p = <0.0001) where women, independent from whether they were pregnant or not, showed a greater RPW ratio while standing on a stable surface (79.35%) compared to an unstable surface (62.57%).

Table 8

Third trimester vs. non-pregnant

	T3 (n = 12)	Non-pregnant (n = 20)
COP displacement, Ankle, Stable (cm)	-1.41 ±0.87	-1.45 ± 0.69
COP displacement, Ankle, Unstable (cm)	-0.97 ± 0.55	-0.98 ± 0.53
COP displacement, Back, Stable (cm)	0.34 ± 0.24	0.16 ± 0.30
COP displacement, Back, Unstable (cm)	0.30 ± 0.54	0.56 ± 0.34
RPW (%), Stable	76.35 ± 11.43	82.34 ±16.59
RPW (%), Unstable	65.23 ± 18.53	59.91 ± 19.04

The values are means with standard deviations if data was normally distributed. RPW: relative proprioceptive weighting; COP: center of pressure.

Table 9

Third trimester vs. non-pregnant student's t post-hoc tests

		Test statistic	p-value
COP displacement, Back	T3 vs non-pregnant on stable surface	1,43	0,16
	T3 vs non-pregnant on unstable surface	-1,98	0,05
	Stable vs unstable in non-pregnant women	4.20	**0.0002**
	Stable vs unstable in non-pregnant women	-0.36	0.72

COP: center of pressure; NP: non-pregnant; **p <0.05** means significant difference.

5. Discussion

5.1. Reflection on the findings in function of research question

5.1.1. Pregnant women first trimester vs. third trimester

Our results demonstrated that pregnant women in their first trimester had an increase in reliance on ankle muscle proprioception, compared to their third trimester of pregnancy, independent of the support surface they are standing on. Furthermore, all pregnant women showed a decrease in reliance on ankle muscle proprioception while standing on an unstable support surface, compared to a stable support surface. However, reliance on ankle muscle proprioception was not affected by the interaction of the time and support surface. Furthermore, this interaction effect was also not significant for the use of ankle muscle proprioception compared to back muscle proprioception, or the reliance on back proprioception. Finally, there was no difference in reliance on back proprioception between the first and third trimester of pregnancy, and between a stable and unstable support surface, which can also be applied to the use of ankle muscle proprioception compared to back muscle proprioception.

5.1.2. Pregnant women in their first trimester vs. non-pregnant

Pregnant women in their first trimester showed an increased reliance on ankle muscle proprioception compared to non-pregnant women, independent of the used support surface. Moreover, pregnant, and non-pregnant women all showed a decrease in reliance on their ankle muscle proprioception while standing on an unstable support surface, compared to a stable support surface. The reliance on back proprioception of all these women is increased on the unstable support surface, compared to the stable support surface. These women all showed a relatively less dominant use of ankle muscle proprioception compared to back muscle proprioception while standing on an unstable support surface, indicating a more multisegmental strategy to maintain stability. Still, there was no effect on reliance on ankle muscle proprioception by the interaction of the group and support surface. Furthermore, the use of ankle muscle proprioception compared to back muscle proprioception, or the reliance on back proprioception were not affected by this interaction or by the group women belonged to.

5.1.3. Pregnant women in their third trimester vs. non-pregnant women

Independent from being pregnant or not, women showed a decrease in reliance on ankle muscle proprioception while standing on an unstable support surface, compared to a stable support surface. Post-hoc tests performed to examine the significant interaction effect, revealed that non-pregnant women had an increased reliance on back proprioception while standing on an unstable support, compared to a stable support surface. Since this was not seen in pregnant women in their third trimester for this condition, meaning their reliance on back proprioception was less in this condition and thus they still used an ankle steered strategy. In addition, there was a relatively less dominant use of ankle muscle proprioception compared to back muscle proprioception for all these women on the unstable support surface, indicating that they all switched to a multisegmental strategy in this condition. Finally, the reliance on ankle muscle proprioception was not affected by the interaction of the group and support surface, or the group women belonged to. This last also applies to the use of ankle muscle proprioception compared to back muscle proprioception.

5.2. Underlying mechanisms explaining the effects of local muscle vibration on COP variables

5.2.1. Pregnant women first trimester vs. third trimester

An increase in reliance on ankle muscle proprioception was found in pregnant women in their first trimester, compared to their third trimester of pregnancy, independent of the support surface they were standing on. This increase might lead to less capacity of these women to switch to a multisegmental strategy to maintain balance, especially in more challenging dynamic tasks (e.g., sit-to-stand-to-sit, forward bending, lifting a load,...) (Brumagne et al., 2008). The disturbed use of proprioception found in our study is in contradiction with the increased anterior-posterior COP sway and reduced postural stability throughout pregnancy found in other studies that demonstrate a higher use of ankle proprioception in third trimester of pregnancy (Butler et al., 2006; Inanir et al., 2014; Jang et al., 2008; McCrory et al., 2010; Oliveira et al., 2009). Moreover, in healthy individuals, the application of ankle muscle vibration was associated with a greater COP displacement in posterior direction in relation to the center of the platform during baseline recording, as an immediate reaction to proprioceptive perturbations (Duclos et al., 2014). In our study, the statistical test shows that women in their third trimester use less ankle proprioception compared to their first trimester of pregnancy. This may suggest that changes in biomechanics throughout pregnancy have an influence on the proprioceptive weighting of pregnant women during postural control. However, the exact role of proprioceptive weighting of these muscles in pregnant women with postural control is not known (Bloem et al., 2000; Sorensen et al., 2002). A potential hypothesis is the influence of abdominal muscle lengthening during pregnancy on postural control. This might be explained by the change in the proprioceptive input given by the muscle spindles, as feedback in response to the length of the muscle-tendon complex and the fiber force-length relation (Iqbal and Roy, 2009). Another possibility that explains the difference in postural control throughout pregnancy, is the shift in center of gravity seen due to the growing fetus which affects postural stability (Cakmak et al., 2016). However, this suggestion is contradicted by our findings that reliance on ankle muscle proprioception during postural control is increased in the first trimester of pregnancy.

The reliance on back proprioception was not different between pregnant women in their first and third trimester, or between stable and unstable support surfaces. Lee et al. (2012), Lee et al. (2013), and Martin et al. (2015) showed no significant COP displacement during back vibration in healthy individuals. They explain this by the reorganization of posture in response to sensory feedback to control the center of mass, resulting in a multi-segmental strategy. This suggests that the pregnant women in this study were able to adjust the information of their back to interpret the internal spinal representation of their body (Martin et al., 2015).

The dominant use of ankle muscle proprioception compared to back muscle proprioception was not different between the first and third trimester of pregnancy, or between the stable and unstable support surfaces. In healthy individuals, standing on an unstable support surface leads to a decrease in RPW-ratio compared to a stable support surface, indicating they still can adapt their postural control strategy when needed (Brumagne et al., 2008). Since this is not the case in pregnant women, this might demonstrate the remained high reliance on ankle muscle proprioception while standing on an unstable support surface (Brumagne et al., 2008; Ivanenko et al., 1999). The study of Claeys et al. (2015) confirms the reliance on ankle muscle proprioception as indicator for measuring RPW-ratio. These results indicate that pregnant women might have difficulty with adapting their postural control in response to more challenging situations (e.g., unstable support surfaces, unipedal stance, smaller base of support...) (Brumagne et al., 2008).

5.2.2. Pregnant women in their first trimester vs. non-pregnant women

Pregnant women in their first trimester relied more on ankle muscle proprioception compared to non-pregnant women. The same difference is seen between healthy individuals and individuals with recurrent low back pain (Brumagne et al., 2008). Individuals with recurrent low back pain seemed to show a greater COP displacement during ankle muscle vibration while standing on a stable and unstable support surface, compared to healthy individuals (Brumagne et al., 2008). These findings suggest the altered postural control strategy in favor of ankle muscle proprioception in this population, which leads to less balance when postural control is more challenging (Brumagne et al., 2008). Since some pregnant women in our study had a history of low back pain and experienced low back pain during their first trimester of pregnancy, it is possible to reflect the outcomes of Brumagne et al. (2008) to our results. However, this does not explain the potential effect of biomechanical changes, such as BMI and body curvature, related to pregnancy on their proprioceptive weighting during ankle muscle vibration. A possible explanation for the increased reliance on ankle muscle proprioception in the first trimester of pregnancy is the effect of hormonal changes that are already present during this phase of pregnancy. Increased levels of estradiol, progesterone, cortisol, and relaxine are seen in the first trimester, compared to more stabilization of these hormones during the second and third trimester of pregnancy (Fan et al., 2009; Quagliarello et al., 1979; Rungee, 1993). This increased amount of relaxine may cause sacroiliac joint laxity related to instability and dysfunction of the pelvic region, which in its turn can lead to postural instability (Berg et al., 1988; Calguneri et al., 1982; Marnach et al., 2003). Furthermore, it is demonstrated that women in their first trimester of pregnancy experience higher levels of depression and anxiety, compared to their second and third trimester of pregnancy (Baker et al., 2008; Fan et al., 2009; Schneider et al., 2008). This can be related to physiological and emotional changes, such as vomiting, transformation of the body, financial concerns, worries about the development and health of the fetus, and interpersonal relations (Fan et al., 2009). Ohno et al. (2004) showed a positive correlation between the change in area of body sway and maximum length of anterior-posterior body sway with the changes in state anxiety, meaning individuals with greater anxiety had less stability to maintain balance. Individuals with symptoms of depression also showed greater postural instability when performing a dual task on a stable support surface, and even more instability when the difficulty of the task was increased (Doumas et al., 2012). This was investigated by the other master thesis duo of this research group in their study called: “The correlation of body perception with pain intensity, disability and psychological factors in the first and third trimester of pregnancy among multiparous women.”

5.2.3. Pregnant women in their third trimester vs. non-pregnant women

All women had a decrease in reliance on ankle muscle proprioception while standing on an unstable support surface, compared to a stable support surface. This switch to a more multi-segmental postural control strategy is reasonable because the reliance on ankle muscle proprioception is not sufficient in this condition. This effect can be declared by the same way this was done in pregnant women in their first trimester and non-pregnant women, since the effect is independent from pregnancy.

Post-hoc tests of the interaction effect revealed that non-pregnant women had an increased reliance on back proprioception while standing on an unstable support surface, compared to pregnant women in their third trimester of pregnancy. This less dominant use of ankle muscle proprioception compared to back proprioception on an unstable support surface in non-pregnant women, was also seen in the study of Brumagne et al. (2008), where healthy individuals were able to switch to a multisegmental strategy for postural control. This might indicate that women in their third trimester of pregnancy used a more ankle steered proprioceptive strategy (Brumagne et al., 2008; Ivanenko et al., 1999). This can result in more challenges to maintain balance when performing more demanding postural tasks (e.g., unstable support surfaces, unipedal stance, smaller base of support...) (Brumagne et al., 2008).

5.3. Strengths and limitations

This study has multiple weaknesses. First of all, we have a small sample size in each group and very homogeneous groups (e.g., age), which makes the results less generalizable to the entire population. The small sample size could be due to covid-19 that many pregnant women did not want to take any risks by participating in our study. Secondly the research design assumes voluntary participation, which results in a non-participation bias, because perhaps only interested, motivated, sporty, body-conscious women will participate. Another limitation of this study is that only static postural tasks (standing on a stable and unstable surface with and without muscle vibration) were evaluated. During more dynamic tasks (e.g., sit-to-stand-to-sit, forward bending, lifting a load,...) the role of proprioceptive adaptations could give more insights in postural control. In this study a six-channel force plate (AMTI, USA) was used to assess the center of pressure, which is one of the most common used equipment (Claeys et al., 2011; Claeys et al., 2012; Claeys et al., 2015; Janssens et al., 2016; Goossens et al., 2019). But this also has its limitations such as being expensive and not being transportable therefore there will be a low application in clinical practice. Lastly, the effect of other factors (e.g., psychosocial, low back pain) that could influence postural control and their correlation with vibration and support surface was not investigated. This study also has strengths. First, there was a standardization of the testing procedure in both the pregnant- and the non-pregnant participants. Foot position was determined using a transparent sheet and for occlusion of vision the same pair of non-transparent glasses were used. The test procedure was performed by the same person each time. This means that there is consistency in the results and therefore less measurement error. Secondly, there was a follow-up of the pregnant participants which allowed them to compare themselves at various times of pregnancy. A control group (non-pregnant women) was present which makes it possible to know which sensory system is altered during pregnancy. For muscle vibration, the muscle vibrators of Maxon Motors, Switzerland, 60 Hz, 0.5 mm, were used. These are used in numerous studies (Kiers et al., 2015; Claeys et al., 2011; Janssens et al., 2016). It is important to apply the muscle vibrators with the same pressure over the same location (Kiers et al., 2015), because the same researcher always applied the vibrators, there is little or no difference between the participants. Lastly, a limited number of COP parameters are used that appear in different studies (Claeys et al., 2011; Claeys et al., 2012; Claeys et al., 2015; Goossens et al., 2019; Janssens., 2016). This also makes it easier to derive conclusions from these.

5.4. Future research and clinical implications

First recommendation for future research is to include more participants, as well as a more heterogeneous group of participants in order to generalize findings to this population. In addition, a follow-up period of the pregnant participants post-partum and perhaps during the next pregnancy could be interesting to investigate if changes in sensory systems persist or appear.

This study did not measure the effect of PLPP alone and its correlation with vibration and support surface on postural control. Recent studies show that up to 77% of pregnant women suffer from PLPP during their pregnancy (Bergström et al., 2014). Most women recover from PLPP within three months of delivery, but 5% do not (Bergström et al., 2014; Wu et al., 2004; Gutke et al., 2006). It could be an interesting factor to include its effect on postural control and the underlying mechanisms in further research.

As mentioned earlier there were only static postural tasks included in this study. Therefore, future research should include more dynamic tasks (e.g., sit-to-stand-to-sit, forward bending, lifting a load,...) to give more insights in postural control during more functional tasks of daily living and their underlying mechanisms.

In this study there was no assessment of factors (e.g., psychosocial, low back pain) that could influence postural control. By other research it has been shown that this could have an influence (Harringe et al., 2008; Mann et al., 2010; Zhang et al., 2020; Ohno et al., 2004). Therefore, we would recommend that this should be included in subsequent research.

6. Conclusion

The weighting of proprioceptive input plays an important role in maintaining postural stability in pregnant women. To investigate the influence of pregnancy on this postural control, we evaluated the differences in proprioceptive weighting among pregnant women in their first and third trimester and between non-pregnant women and women in their first and third trimester of pregnancy.

Our results showed that there was a significant difference of proprioceptive weighting between pregnant women in their first and third trimester, showing more reliance on ankle muscle proprioception in the first trimester of pregnancy, independent from the support surface they were standing on. Moreover, this was also seen in pregnant women in their first trimester compared to non-pregnant women. Comparing women in their third trimester of pregnancy to non-pregnant women, there was a significant increase in reliance on back proprioception in non-pregnant women standing on an unstable support surface. This indicates that pregnant women in their third trimester used a more ankle steered strategy to maintain balance. These findings may suggest that changes in biomechanics throughout pregnancy might have an influence on the proprioceptive weighting of pregnant women, but its exact role in pregnant women needs further investigation.

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INVENTARISATIEFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
04/10/2021	Opstart MP 2 (online overleg)	Promotor: Prof. Dr. Janssens Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
12/10/2021	Vragen over rekrutering (mail)	Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
19/10/2021 t.e.m. 25/11/2021	Rekruteren en testen van proefpersonen	Promotor: Prof. Dr. Janssens Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
22/11/2021	Bespreking data-analyse (mail)	Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
30/11/2021 3/12/2021 8/12/2021	Feedback inleiding (mail)	Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
30/11/2021	Dataset ontvangen (mail)	Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
3/12/2021	Feedback methode (mail)	Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
10/12/2021 14/12/2021 20/12/2021	Vragen en feedback statistiek (mail)	Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren

		Student(e): Laura Jochmans
06/02/2022	Opstellen van deadlines (mail)	Promotor: Prof. Dr. Janssens Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
14/02/2022	Bespreking en feedback statistiek en resultaten (online overleg)	Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
22/12/2021 13/03/2022 3/04/2022	Feedback resultaten (mail)	Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
11/05/2022 12/05/2022	Feedback discussie (mail	Copromotor/Begeleider: Dr. Goossens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans
16/05/2022	Feedback gehele MP (mail)	Promotor: Prof.Dr. Janssens Student(e): Frauke Vercalsteren Student(e): Laura Jochmans

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

Naam Student(e): ……Laura Jochmans en Frauke Vercalsteren……………………
Datum:……30/05/2022………………

Titel Masterproef:
……Propioceptive weighting during postural control in pregnant and non-pregnant women
…………

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	X	O	O	O	O	O
Methodologische uitwerking	X	O	O	O	O	O
Data acquisitie	O	O	O	O	X	O
Data management	O	O	O	X	O	O
Dataverwerking/Statistiek	O	O	O	X	O	O
Rapportage	O	O	O	X	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)
06/06/2022
Frauke Jochmans

Datum en handtekening promotor(en)
30/05/2022

Datum en handtekening Co-promotor(en)

Lotte JANSSENS

aan Nina, Laura, mij

25 mei 2022 21:38 (2 dagen geleden)

Beste Laura en Frauke,

Bijgevoegd alvast de handtekeningen op de 3 formulieren met gunstig advies die jullie dan maandag meteen kunnen uploaden.
We zullen jullie volgende week nog de laatste feedback geven op de herwerkte discussie.
Succes met de laatste loodjes.

Mvg,

Lotte Janssens

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: **1643522 Jochmans Laura**
Student number + name

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

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:*

X behouden - *keep* Propioceptive weighting during postural control in pregnant and non-pregnant women

O wijzigen - *change to*:

/:

X 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)*:

X O behouden - *keep* Frauke Vercalsteren

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:*

X O goedgekeurd - *approved*

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

Scriptie/*Thesis:*

X O openbaar (beschikbaar in de document server van de universiteit)- *public (available in document server of university)*

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

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

X O 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*

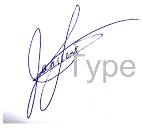
LUIK D - VERPLICHT - IN TE VULLEN DOOR DE STUDENT EN DE PROMOTOR(EN)
PART D - MANDATORY - TO BE FILLED OUT BY THE STUDENT AND THE SUPERVISOR(S)

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

30/05/2022

Datum en handtekening promotor(en)
Date and signature supervisor(s)

30/05/2022



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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: **1642949 Vercalsteren Frauke**
Student number + name

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

INSTRUCTIES - *INSTRUCTIONS*

Neem onderstaande informatie grondig door.

Print dit document en vul het aan met DRUKLETTERS.

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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:*

X behouden - *keep* Proprioceptive weighting during postural control in pregnant and non-pregnant women.

O wijzigen - *change to*:

/:

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

Juryverdediging/*Jury Defense:*

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☒ 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)

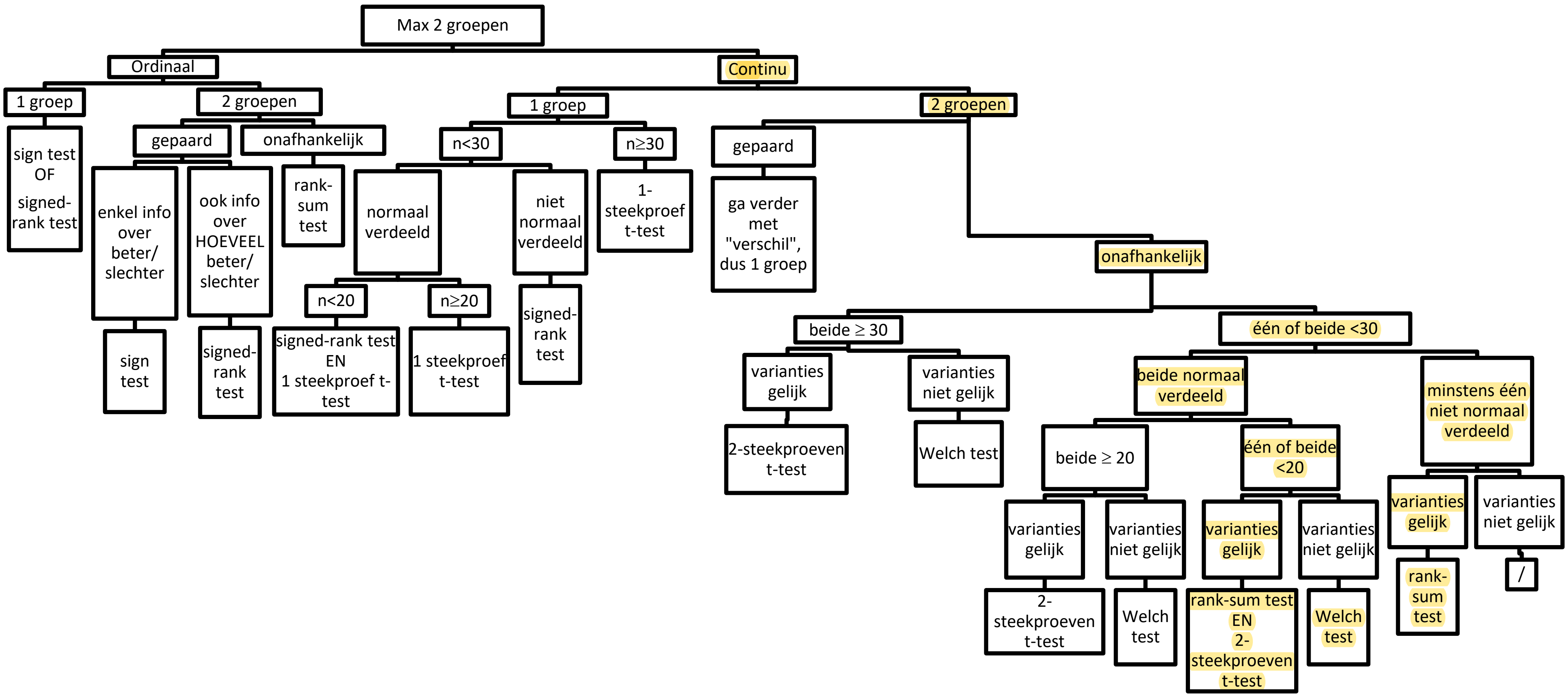
Datum en handtekening student(en)
Date and signature student(s)

30/05/2022

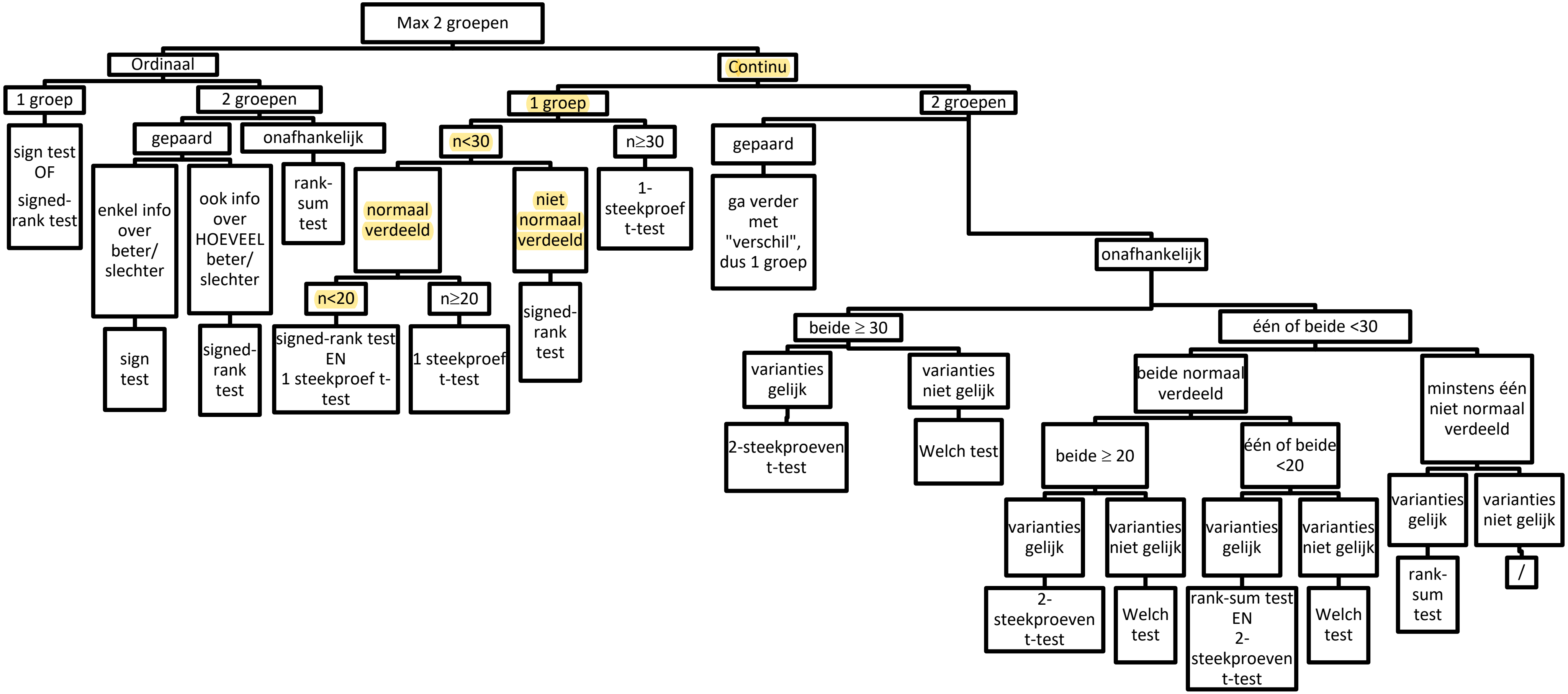
Datum en handtekening promotor(en)
Date and signature supervisor(s)

30/05/2022

T1/T3 vs. non-pregnant women



T1 vs. T3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