Gender specific outcomes of the Neuromuscular Control tests with the Sensamove® therapy cushion

Experimental study

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Preface

This research was conducted in the context of the bachelor of physiotherapy at Fontys University of Applied Sciences, with the collaboration of the company Sensamove®, which created the product tested in this research.

First of all, I would like to thank my supervisor, Annelies Simons, for her commitment, feedback and guidance throughout this project. I would also like to thank my second assessor, Tim van der Stam, for his help and useful critics.

I would like to share my gratitude to my peer researcher and friend, Simon Masoner, whose collaboration, encouragement and understanding carried me through this thesis.

I would like to thank my family and friends for their insight and support.

I would also like to thank all the participants who joined the project and showed interest in the research.

Thanks to all these people, this thesis has brought me a lot, not only in terms of academic development, but also in terms of inner human development, on a personal and on a professional level as a future physiotherapist.

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Abstract

***Background*:** Low Back Pain (LBP) is very common[1] and efforts are made to find effective treatment. Training postural control can help recovering from LBP[2][3]. The Sensamove® therapy cushion in combination with the Neuromuscular control (NMC) tests were created to help train and test postural control in sitting[4] by assessing the position of the pelvis.

Objective: The purpose of this study was to provide norm values for the outcomes of the NMC tests with the Sensamove® therapy cushion in 18 to 30 year-old healthy adults and find out whether there are differences in the outcomes between men and women.

Method: The NMC tests consist of seven tests challenging static balance (with and without visual feedback) and dynamic balance. The general performance (%), of all tests were studied. Average deviations, maximum deviations, maximum ranges, speed and smoothness of movement were studied in two tests. Outcomes were analysed for gender differences. Weight, height and hip circumference were studied for gender differences and correlation with general performance.

***Results*:** 112 participants (58 females and 54 males) took part in the study. The average general performance for the whole group ranged from 80% to 97%, among which, the static balance test with visual feedback reached the highest scores (97% on average for both groups). There was no statistically significant gender difference in the outcomes of the NMC tests. However women performed more smoothly than men in the dynamic left-right test, while men performed more smoothly than women in the dynamic front-back test. There was a statistically significant gender difference in weight, height and hip circumference but no correlation was found with the general performance percentages.

Conclusion: No statistically significant gender difference was found, even when weight, height or hip circumference differed.

Keywords: balance, posture, gender, differences, pelvis anatomy, low back pain, sitting

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1. Introduction

The global prevalence of low back pain (LBP) throughout the world, regardless of prevalence period is 31%[5]. LBP is the most common musculoskeletal conditions[1] and it is therefore important for health care professionals to find out about ways to treat it. LBP can be initiated by tissue strain caused by impairments like trunk postural deficits, characterized by spinal instability or dysfunction, muscular imbalance or weakness and proprioceptive or neuromuscular deficits[6][7][8][9].

Training postural control and adopting a better lumbar posture are key factors for recovering from LBP[2][3][10]. Scannell JP and McGill SM[3] carried out research on the position of the lumbar spine during the activities of daily living (ADL) sitting, standing and walking, and found out that the posture of the subjects (hypolordotic, hyperlordotic or without any lumbar spine impairment) had an impact on lumbar passive tissue strain. The subjects took part in a 12 week exercise program for improving lumbar posture which resulted in a decrease in tissue strain during ADL for all participants.

In sitting, compared with standing, the centre of gravity of the body is closer to the base of support (BOS)[11], which facilitates balance and postural control[12][13]. Nevertheless, in sitting position, stability and trunk control are necessary to perform ADL[14]. Whether it be for someone obliged to sit in a wheelchair, a student or a working person sitting behind a desk all day long or an old person spending a lot of time sitting at home, a good postural control in sitting is necessary to function in daily life and decrease passive tissue strain to prevent LBP[3][14].

This study focuses on the use of a therapy cushion in sitting position for training postural control[4]. This therapy cushion, developed by Sensamove®, is filled with air and embedded with a sensor which detects movement; it is connected to a computer through a cable. A programme on the computer processes the information sent by the cushion and provides visual feedback to the user about the position of his/her pelvis. Since the pelvis and the spine are anatomically joined and closely related[11],it gives feedback on the position of the user's spine and promotes postural learning[4][15][16].

The software includes several games and neuromuscular control tests. The Neuromuscular Control tests, or NMC tests, which will be used for this experimental study, are a series of seven tests which aim to challenge static and dynamic balance, proprioception, neuromuscular coordination and core stability[4]. The NMC tests aim to give an indication of the level of all these skills[4].

However since the Sensamove® therapy cushion along with its software are relatively recent inventions, no norm values have yet been established to indicate precisely the level of the user. The aim of this experiment is to establish norm values for the Sensamove® therapy cushion NMC tests in 18 to 30 year-old healthy adults. Nonetheless, norm values may have to be specific to gender.

The reason why differences might be expected in men compared to women, is because in terms of anatomy, the pelvic area, used during therapy cushion testing, is the part of the body where there are the most gender related differences: organs, muscles, muscle mass, body fat mass, bony mass and shape of bones all differ according to gender[11]. On a structural level, the female pelvic girdle is broader, lighter, more shallow, adapted to childbirth and more tilted forward than the male pelvic girdle, which in contrast, is taller, heavier, more narrow and adapted to the support of a heavier load[17]. Such anatomical differences could potentially affect the way men and women move and use their pelvis on the Sensamove® therapy cushion as it is the case that they move their pelvis differently when doing a single leg squat[18].

Hypothetically, based on the differences mentioned above, gender might induce differences in the general performance of the NMC tests, expressed in percentages. It might also reveal differences in deviations, expressed in degrees, and quality of movement (if the movement is smooth or jerky). The various types of tests (static, dynamic, open eyes or closed eyes tests) may uncover gender differences.

Factors such as weight, height and hip circumference might also affect the results and will therefore be studied with a view to detect gender differences.

Concerning weight, it has been shown that an increased body weight is correlated to a decrease in balance stability and control[19]. Heavy participants are therefore expected to display worse balance skills.
Despite the fact that no consistent study has been found suggesting that height may have an influence on balance, core stability or any other skills challenged by the NMC tests using the Sensamove® therapy cushion, height may affect the way tests are carried out and will therefore be measured. The taller a person is, the further their centre of gravity is from the BOS[11], and this might cause postural control and balance to be more challenging. Very tall participants are expected to have worse outcomes.
Hip circumference is measured because during the Sensamove® therapy cushion NMC tests the hip circumference represents the size of the BOS for the test. In this study, the assumption is made that wider hips may provide more support and thus more stability.

The aim of this study is to find out whether it is relevant to differentiate Sensamove® therapy cushion NMC tests norm values for men and for women. The following research question was formulated to provide the desired information for this study:

What possible differences are revealed in the outcomes of the Sensamove® therapy cushion NMC tests between 18 to 30 year-old healthy men and 18 to 30 year-old healthy women?

2. Method

2.1 Study design

This was a quantitative experimental research focused on finding out whether there was a gender difference in the outcomes of the Sensamove® NMC tests. This research was done in collaboration with Fontys Paramedical University of Applied Sciences in Eindhoven and the company Sensamove® in Utrecht. The NMC tests were performed in a randomized order to prevent order bias. The random order was set using the random integer set generator RANDOM.ORG[20].

2.2 Participants of the study: subject recruitment

120 people were recruited at Fontys University of Applied Sciences TF Building in Eindhoven, Technical University Eindhoven and Design Academy Eindhoven. Both sexes were equally represented. An information letter (appendices I and II) and invitation letter (appendices III and IV) were sent out by webmail. Promotion for joining the experiment was made at the end of classes at Fontys University of Applied Sciences in Eindhoven as well as on social media platforms. The people invited to the experiment were asked to make an appointment at the time that suited them on an online booking platform created especially for this occasion with YouCanBook.Me[21]. The participants were included or excluded according to the inclusion and exclusion criteria (table 1).

Table 1: Inclusion and exclusion criteria for participation

Inclusion	Exclusion
• Age: 18 to 30 years • Healthy young adults	• Specific or non-specific current lower back pain. Justification: Leads to impaired performance, due to lack of proprioceptive postural control strategies[22]. • Serious medical condition (cardiovascular-, neurological disorders). Justification: Could lead to unexpected complications during the tests. • Diagnosed with any balance disorder (vestibular organ dysfunction, benign paroxysmal positional vertigo -BPPV-…). Justification: Risk of injury during the tests and disorder might influence performance. • Use of medication affecting balance or vision. Justification: Certain medications have a strong effect on the body causing e.g. blurry vision or dizziness. • High intensity core training previously to testing on the same day. Justification: Tired and sore muscles might lead to poorer performance. • Pregnant women. Justification: Joint laxity, weight gain and forward shifting of the centre of gravity take place during pregnancy. This leads to lumbar spine hyperlordosis, anterior tilting of the pelvis and increased static and dynamic loads exerted on the axial skeletal, all of which affect the weight distribution and posture of pregnant women. Additionally low back pain and/or pelvic girdle pain are very common complaints during pregnancy[23]. • Being free of any previous injury or surgery on the back, spine, pelvic or abdominal area over the past six months. Justification: Pain, sensibility disturbances and fresh scars might influence performance.

Inclusion	Exclusion
	• For women, complaints associated with menstruations like pain in the lower back, tiredness, general weakness or weakness in the legs. Justification: Pain, tiredness or weakness associated to menstruations may alter performance. • Current medical condition impairing performance (fever, cold, headache, dizziness, feeling of sickness…). Justification: Performance might be altered due to medical condition. • Visual impairments that cannot be corrected with glasses. Justification: Negative effect on postural control[24].

2.3 Measurement tools and their justification:

The Sensamove® Therapy Cushion in combination with the Sensbalance Software (Version 2.3.0 build 384) was used to perform the NMC tests. Up to now, no research has been done on the NMC tests in combination with the Sensamove® therapy cushion. The reliability of the NMC tests in combination with the Sensamove® balance miniboard in young adults has been tested[25]. Results suggest that the Sensbalance MiniBoard and interactive training software NMC can be used as an objective assessment tool for evaluating balance skills with cautions and perhaps along with additional testing tools. It has also been shown that the usage of this tool as a training equipment may not only help balance skills, but also benefit neuromuscular control, proprioception and motivation[25].

Weight and Height were measured with a height and weight scale, (Model: DS-103, Dong Sahn Fenix, Seoul, Korea) which were used in combination with the software Total Health Promotion Plan THP2 (Copyright 2010).

Hip circumference was measured according to the World Health Organization (WHO) STEPwise Approach to Surveillance (STEPS) Manual[26] by using a constant tension tape at the maximum circumference over the buttocks. In order to do this, participants were asked to lower their trousers a bit. The STEPS Manual provides a standardized protocol for collecting data on hip circumference amongst other measurements. The STEPS Manual is widely used but has not been tested for reliability yet.

2.4 Measurement procedure

The experiment took place in the Health check room of Fontys University of Applied Sciences, located at Dominee Theodoor Fliednerstraat 2, 5600AH Eindhoven. The whole experiment lasted 30 minutes per participant.

The participant entered the experiment room and was asked to read the information letter (appendices I and II) if he/she had not read it on forehand. The participant then signed the informed consent (appendices V and VI). The researchers gave a brief introduction about the experimental procedure and the participant was given the opportunity to ask questions. Personal details (name, age, gender, student number, occupation…) of the participant were then registered in the Total Health Computer

Software (THCS). Weight and height were measured (appendix VII). Data was then gathered on hip circumference by means of a constant tension tape. Once the data was collected and recorded on the THCS, the equipment, software and subject were set according to protocol (appendix VIII), followed by calibration of the cushion. The participant sat down on the therapy cushion and began with the following seven NMC tests:

- *Static balance test with visual feedback (test 1)*
- *Static balance test with eyes closed -proprioception- (test 2)*
- *Dynamic left-right balance test (test 3)*
- *Dynamic front-back balance test (test 4)*
- *Dynamic cross-diagonal balance test (test 5)*
- *Dynamic donut balance test (test 6)*
- *Dynamic circle balance test (test 7)*

The participant performed one test at a time according to a random order (appendix IX). For detailed information about the tests procedures, see the NMC tests protocol in the appendix VIII.
Once the tests were over, the researchers saved the measured data and the participant was thanked and offered a snack.
5 to 12 participants a day took part in the experiment which was spread out over 4 weeks in order to reach 120 sets of results.

2.5 Statistical analysis

On the one hand, descriptive statistics were done to gather information about the demographic and outcome variables for the whole population as well as for men and women separately. On the other hand, inferential statistics were done to test whether these demographic and outcome variables were statistically significant different between men and women.
Additionally, in the case that weight, height and hip circumference were statistically significant different for males and females, a correlation test was run to see if there was a correlation between the following variables:

- weight and general performance of all seven NMC tests separately
- height and general performance of all seven NMC tests separately
- hip circumference and general performance of all seven NMC tests separately

The Kolmogorov-Smirnov test was used to find out whether the data was normally distributed or not. Where $P > 0.05$, the data was normally distributed. Where $P < 0.05$, the data was not normally

distributed. For normally distributed data, the mean and standard deviation values were used. For not normally distributed data, the median and interquartile range were used.

Descriptive statistics:

Demographic variables:

Table 2: Demographic variables

Variable	Type	Description
Gender	Independent, Categorical nominal	Male or Female
Age	Independent, Numerical continuous	Years between 18 and 30
Weight	Independent, Numerical continuous	kg
Height	Independent, Numerical continuous	cm
Hip circumference	Independent, Numerical continuous	cm

kg: kilograms
cm: centimetres

Outcome variables:

Table 3: Outcome variables

Variable	Tests	Description	Type
General performance (or "overall score")**	1 to 7*	Average of the general performance percentages of all participants for each tests 1 to 7* separately	Dependent, Numerical continuous
Front average deviation	3*	Average of the front average deviations in degrees of all participants for test 3*	Dependent, Numerical continuous
Back average deviation	3*	Average of the back average deviations in degrees of all participants for test 3*	Dependent, Numerical continuous
Left average deviation**	4*	Average of the left average deviations in degrees of all participants for test 4*	Dependent, Numerical continuous
Right average deviation**	4*	Average of the right average deviations in degrees of all participants for test 4*	Dependent, Numerical continuous
Front maximum deviation	3*	Average of the front maximum deviations in degrees of all participants for test 3*	Dependent, Numerical continuous
Back maximum deviation	3*	Average of the back maximum deviations in degrees of all participants for test 3*	Dependent, Numerical continuous
Left maximum deviation**	4*	Average of the left maximum deviations in degrees of all participants for test 4*	Dependent, Numerical continuous
Right maximum deviation**	4*	Average of the right maximum deviations in degrees of all participants for test 4*	Dependent, Numerical continuous
Front-back maximum range	3*	Maximum range in degrees of the front-back deviations of all participants for test 3*	Dependent, Numerical continuous
Left-right maximum range**	4*	Maximum range in degrees of the left-right deviations of all participants for test 4*	Dependent, Numerical continuous
Left-right average speed**	3*	Average number of times the participant reaches a side (left or right)	Dependent, Numerical continuous
Front-back average speed	4*	Average number of times the participant goes back and forth (front or back)	Dependent, Numerical continuous
Smoothness of left-right movements**	3*	Percentage of smooth movement performances in test 3*	Dependent, Numerical continuous
Smoothness of front-back movements	4*	Percentage of smooth movement performances in test 4*	Dependent, Numerical continuous

*: see Appendix VIII
**: see Appendix X
1: Static balance test; 2: Static balance test with eyes closed (proprioception); 3: Dynamic left-right balance test; 4: Dynamic front-back balance test; 5: Dynamic cross-diagonal balance test; 6: Dynamic donut balance test; 7: Dynamic circle balance test

The general performance (or overall score) was studied for all tests 1 to 7. For tests 3 (dynamic left-right balance test) and 4 (dynamic front-back balance test), average deviations, maximum deviations, maximum ranges, average speed and smoothness of movement were also studied. The choice of

selecting tests 3 and 4 for more detailed analysis was made because these tests are the only ones where all the above outcome variables could be studied and because tests 3 and 4 could be directly compared to one another.

Average and maximum deviations:

Figure 1

In test 3, participants were asked to move sideways: average and maximum deviations to front and back (represented by an orange arrow in figure 1) were measured to see how much the participants deviated from the given direction left-right.

In test 4, participants were asked to move from front to back: average and maximum deviations to left and right (represented by an orange arrow in figure 2) were measured to see how much the participants deviated from the given direction front-back.

Figure 2

Maximum range:

The front-back maximum range corresponded to the sum of the maximum deviation to the front and the maximum deviation to the back (without taking into account minus signs). The left-right maximum range corresponded to the sum of the maximum deviation to the left and the maximum deviation to the right (without taking into account minus signs).

Maximum deviations to the back and to the left were automatically set as negative numbers, therefore when calculating the maximum range, minus signs were not taken into account.

Example: Calculation of front-back maximum range with x (front maximum deviation) and y (back maximum deviation)

x + (-y) *will become* *x + y*

Speed:

Figure 3

Speed was calculated in number of back and forth trips:

- from left to right for test 3 -dynamic left-right balance test- (figure 3);
- from front to back for test 4 -dynamic front-back balance test- (figure4).

Figure 4

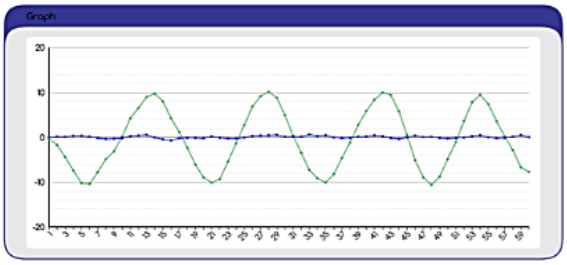
Smoothness of movement:

The smoothness of movement, reflective of the quality of the movement, was graded “smooth”(0) or “not smooth”(1) according to the appearance of the line graph provided by the PDF outcome sheet (see graph 1 and appendix X) for tests 3 and 4 (dynamic left-right and front-back balance tests).

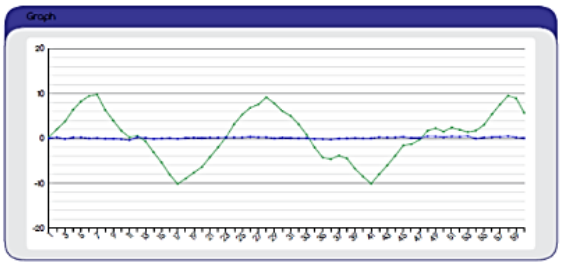
For a graph to be graded “smooth”, the line on the graph needed to be smooth, regular and without any jittery movements throughout the whole test (0).

For a graph to be graded “not smooth”, the line on the graph needed to be jerky, irregular with at least one imperfection in smoothness of the line (1).

The percentage of “smooth” performances in women was compared to the percentage of “smooth” performances in men. A gender difference was expected for the smoothness of movement (see appendix XI for detailed hypothesis).



(0) Fluid, smooth, controlled movement



(1) Jerky, uncontrolled, not smooth movement

Graph 1

Inferential statistics:

Once the data had been tested for normality using the Kolmogorov-Smirnov test, a difference analysis between men and women was performed, therefore the data was unpaired. The difference analysis was run on both demographic and outcome variables.
If continuous data was not normally distributed, the Mann-Whitney U test was used. If it was normally distributed, parametric unpaired t-test was performed.
Results were examined using the P-value to determine whether there was a statistically significant difference between men and women in terms of outcomes of the Sensamove® therapy cushion NMC tests, but also in terms of weight, height and hip circumference.
For each result, if $P < 0.05$, there was a statistically significant gender difference. If $P > 0.05$, there was no statistically significant gender difference.
When using the parametric unpaired t-test, the P-value of the Levene’s test was checked for significance: if it was above 0,05, the t-value and P-value of the parametric unpaired t-test had to be with equal variances assumed; if it was 0,05 or below, the t-value and P-value of the parametric unpaired t-test had to be with equal variances not assumed.

Concerning the outcomes of the Sensamove® therapy cushion NMC tests, gender differences were expected for the general performance of the NMC tests, expressed in percentages. Gender differences were also expected for the deviations in degrees to front, back, and sideways, either in terms of average deviation, maximum deviation or range. The various types of tests (static, dynamic, open eyes or closed eyes tests) were expected to uncover gender differences. The hypothesis of the researcher are stated in appendix XI.

Weight, height and hip circumference were expected to be different for men and women. Men were expected to be taller and heavier, and score lower because of these weight and height differences. Women were expected to have wider hips and score higher because of having a bigger base of support.

As mentioned earlier, if weight, height and hip circumference differed for men and women and that these differences were statistically significant, a correlation test was run.
The Pearson and Spearman tests were used to determine whether there was a correlation between the weight, height and hip circumference of each of the female and male group separately and their respective outcomes in the general performance of all seven NMC tests separately. For normally distributed data, the Pearson correlation coefficient was used. For not normally distributed data, the Spearman correlation coefficient was used.

The closer r_s is to 1, the stronger the correlation between weight or height or hip circumference and the outcomes in the general performance of the NMC tests. From 0.00 to 0.19, the correlation was very weak. From 0.2 to 0.39, the correlation was weak. From 0.4 to 0.59, the correlation was moderate. From 0.6 to 0.79, the correlation was strong. From 0.8 to 1, the correlation was very strong. Besides, the P-value was checked for significance. $P < 0.05$ indicated a correlation while $P > 0.05$ indicated no correlation.

Statistical analysis was performed using SPSS Statistics for Windows, version x.0 (SPSS Inc., Chicago, III., USA).

2.6 Ethical paragraph

Participants of the research were informed about the testing procedure by an information letter and they had to sign an informed consent. Patient privacy was respected; data was handled anonymously with care and only used by the researchers and supervisor. Any results gathered during the tests were not stored or mentioned in combination with names, numbers were used instead, to make it impossible to identify individuals. If a subject wished to obtain his results after the testing, he/she should indicate it on the informed consent. This project has been approved by “Fontys Commissie Ethiek van Onderzoek voor het domein Mens en Maatschappij”.

3. Results

3.1 Participants

In total 120 participants took part in the experiment including 59 (49%) male and 61 (51%) female. 8 participants needed to be excluded altogether. 3 were excluded because they had ongoing back problems, 1 was excluded because of having a fever and 4 were excluded because their data was not recorded properly. Out of the remaining 112 participants, 54 (48%) were male and 58 (52%) were female.

Table 4 sums up the data about the 112 participants. For normally distributed data, the mean and standard deviation values were used. For not normally distributed data, the median and interquartile range were used.

Table 4: participants

Category	Total (n=112)			Female (n=58)			Male (n=54)		
Age (years)	Median	IQR	Range	Median	IQR	Range	Mean	SD	Range
	23	4	18-30	22	3.25	18-30	23	2.49	18-29
Hip circumference (cm)	Median	IQR	Range	Median	IQR	Range	Median	IQR	Range
	95.3	7	83-115	94.3	6.25	83-115	96	8	85-114
Weight (kg)	Mean	SD	Range	Mean	SD	Range	Median	IQR	Range
	72	13.72	49-119	64	9.86	49-89	78	15.25	60-119
Height (cm)	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
	174	9.26	146-196	168	6.16	146-180	181	7.12	163-196

SD: Standard deviation; IQR: Interquartile range

For the total group, the median age was 23 years, the median hip circumference was 95.3cm, the mean weight was 72kg, and the mean height was 174cm. For all of these demographic outcome variables, the male group had higher averages than women (see table 4 for more detail).
There was a statistically significant difference between the weight, height and hip circumference of male and female (table 16 in appendix XII). Men were statistically significant heavier than women ($P<0.05$) as well as statistically significantly taller than women ($P<0.05$). Male participants also had statistically significantly wider hips than women ($P<0.05$).

3.2 General performance

The general performance outcome variable was analyzed for tests 1 (static balance test), 2 (static balance test with eyes closed), 3 (dynamic left-right balance test), 4 (dynamic front-back balance test), 6 (dynamic donut balance test) and 7(dynamic circle balance test).

The results from test 5 -cross-diagonal dynamic balance test- could not be used because the Sensamove® NMC tests software turned out to be wrongly programmed for that particular test.

For test 6, participants were asked to start in the middle before going into the donut and making circles. This means that no participant could have possibly scored 100%.

As it can be seen on table 5, the general performance for both groups were quite high with averages going from 80% to 97% for women and 78% to 97% for men.

Most of the general performance in all the NMC tests presented in table 5 were not normally distributed, therefore median and interquartile range values were retained. Exceptions are marked with a cross. For exceptions, mean and standard deviations were used.

Table 5: General performance of NMC tests 1 to 7 in percentages

	Total (n=112)		Female (n=58)		Male (n=54)	
Outcome	Median	IQR	Median	IQR	Median	IQR
GP Test 1(%)	97	2	97	1.25	97	2
GP Test 2(%)	87	11	87	11	87	11.25
GP Test 3(%)	94	10	94	9.25	94	12
GP Test 4(%)	89	13	89 ┼	8.58 ┼	88 ┼	10.11 ┼
GP Test 6(%)	80	15.75	80	15.25	78 ┼	12.22 ┼
GP Test 7(%)	92	10.75	92	10.25	92	11

IQR: Interquartile range; GP: General Performance

┼ Normally distributed: mean and standard deviations were used instead of median and interquartile range

1: Static balance test; 2: Static balance test with eyes closed (proprioception); 3: Dynamic left-right balance test; 4: Dynamic front-back balance test; 6: Dynamic donut balance test; 7: Dynamic circle balance test

The static balance test with visual feedback was the test where both male and female groups scored the highest (97% on average for both groups). On the contrary, the dynamic donut balance test was the test where both groups scored the lowest (79.5% on average for females and 81.7% on average for males).

The following order, from the test with the highest scores to the test with the lowest scores, was the same for both groups:

- *Static balance test with visual feedback (female and male: 97%)*
- *Dynamic left-right balance test (female and male: 94%)*
- *Dynamic circle balance test (female and male: 92%)*
- *Dynamic front-back balance test (female: 89%; male: 88%)*
- *Static balance test with eyes closed -proprioception- (female and male: 87%)*
- *Dynamic donut balance test (female: 80%; male: 78%)*

The female group scored higher than the male group on four tests, namely tests 1, 3, 4, and 7, whereas the male group scored higher than the female group on two tests, namely tests 2 and 6. However, no statistically significant gender difference was found for any of the general performance of the NMC tests (P>0.05; see table 17 in appendix XII), so all the hypothesis about the general performance outcome variable (table 11 in appendix XI) have to be rejected.

Moreover, no correlation was found between any of the gender specific demographic outcome variables hip circumference, weight or height, and the outcomes of the NMC tests (P>0.05; see table 18, 19 and 20 in appendix XII).

3.3 Other outcomes for tests 3 and 4

Average deviations, maximum deviations, and maximum ranges in tests 3 and 4:

Tests 3 (dynamic left-right balance test) and 4 (dynamic front-back balance test) were looked at more in detail. For these tests, deviations, maximum deviations, maximum ranges, speed and smoothness of movement were analyzed.

During tests 3 and 4, instructions were given to the participant to move in a specific direction (left and right for test 3, front and back for test 4). Deviations from the given direction were studied.

Figure 1

In test 3, participants were asked to move sideways: deviations to front and back (represented by an orange arrow in figure 1) were measured to see how much the participants deviated from the given direction left-right.

Most of the average deviations in NMC test 3 (left-right dynamic balance test) presented in table 6 were not normally distributed, therefore median and interquartile range values were retained. Exceptions are marked with a cross. For exceptions, mean and standard deviation were used.

Table 6: Deviations, maximum deviations and range outcomes for NMC test 3 in degrees

	Total (n=112)			Female (n=58)			Male (n=54)		
Outcome	Median	IQR	Max	Median	IQR	Max	Median	IQR	Max
F avg dev (°)	0.24	0.09	2.38	0.24	0.08	2.04	0.25	0.09	2.38
B avg dev (°)	-0.18	0.09	-1.44	-0.17 ┼	0.07 ┼	-0.89	-0.19	0.09	-1.44
F-B max range (°)	-	-	3.82	-	-	2.93	-	-	3.82

IQR: Interquartile range; Max: Maximum range; F: Front; B: Back; avg dev: average deviation

┼ Normally distributed: mean and standard deviation were used instead of median and interquartile range

In test 4, participants were asked to move from front to back: deviations to left and right (represented by an orange arrow in figure 2) were measured to see how much the participants deviated from the given direction front-back.

Figure 2

The average deviations in NMC test 4 (front-back balance test) presented in table 7 were normally distributed, therefore mean and standard deviation values were retained.

Table 7: Deviations, maximum deviations and range outcomes for NMC test 4 in degrees

	Total (n=112)			Female (n=58)			Male (n=54)		
Outcome	Mean	SD	Max	Mean	SD	Max	Mean	SD	Max
L avg dev (°)	-0.27	0.08	-2.22	-0.26	0.07	-1.39	-0.27	0.09	-2.22
R avg dev (°)	0.23	0.08	1.42	0.23	0.08	1.3	0.23	0.08	1.42
L-R max range (°)	-	-	3.64	-	-	2.69	-	-	3.64

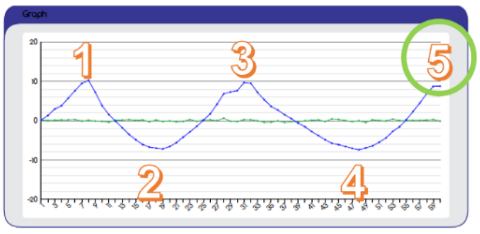
SD: Standard deviation; Max: Maximum; L: Left; R: Right; avg dev: average deviation

For the total group, the front average deviation was 0.24° and the back average deviation was -0.18°, while the left average deviation was -0.27° and the right average deviation was 0.23°.

Men deviated more than women for both tests 3 and 4, with a maximum range for men of 3.82° in test 3 and 3.64° in test 4, and a maximum range for women of 2.93° in test 3 and 2.69° in test 4. However, no statistically significant gender difference was found for any of the average deviations, maximum deviations or maximum ranges of the NMC tests (P>0.05; see tables 21 and 22 in appendix XII), so all the hypothesis about the average deviations, maximum deviations and maximum ranges outcome variables (tables 12 and 13 appendix XI) have to be rejected.

Speed in tests 3 and 4:

The outcome variable speed was studied in tests 3 and 4 because in these tests, speed could be quantified and compared.
Speed was calculated in number of back and forth trips from left to right for test 3 (dynamic left-right balance test) and from front to back for test 4 (dynamic front-back balance test).



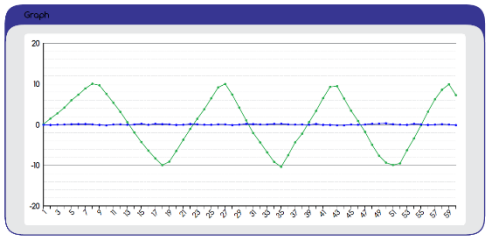
Graph 2

As it can be seen in graph 2, back and forth trips were counted by looking at the graphs provided by the PDF outcome sheets (example in appendix X) for tests 3 and 4.

The average speed for the whole group was 6 numbers of sideways trips for test 3, and 5 numbers of back and forward trips for test 4 (table 23 in appendix XII). No statistically significant gender difference

was found for speed (P>0.05; see table 24 in appendix XII) so all the hypothesis about the outcome variable speed (table 14 in appendix XI) have to be rejected.

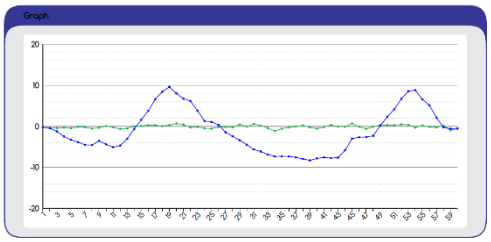
Smoothness in tests 3 and 4:



Graph 3

The smoothness of movement was studied in tests 3 (dynamic left-right balance test) and 4 (dynamic front-back balance test) because the PDF outcome sheets (example in appendix X) of these tests offered the most readable graphs in terms of quality of movement.

Smoothness was graded “smooth” or “not smooth” according to the appearance of the line graph. If the line in the graph was soft, regular and without any jittery movements throughout the whole test, as it is the case in graph 3, the outcome of the test was “smooth”. If the line in the graph was jerky, irregular, with at least one imperfection in continuity of the line, as it is the case in graph 4, the outcome of the test was “not smooth”.



Graph 4

The percentage of smooth performances of the total group was of 51.8% for NMC test 3 and 33% for NMC test 4 (table 8).

In the left-right dynamic balance test, the female group reached 56.9% smooth performances while the male group reached 46.3% smooth performances.

However in the front-back dynamic balance test, the female group reached 27.6% smooth performances while the male group reached 38.9% smooth performances.

Table 8: Smoothness of movement for NMC tests 3 and 4 in percentages

Outcome	Total (n=112)	Female (n=58)	Male (n=54)
Test 3 smoothness (%)	51.8	56.9	46.3
Test 4 smoothness (%)	33	27.6	38.9

3: Dynamic left-right balance test; 4: Dynamic front-back balance test

There was no statistically significant gender difference in smoothness of movement for both tests 3 and 4 (P>0.05; table 25 in appendix XII) so the hypothesis about the outcomes variable smoothness of movement have to be rejected (table 15 in appendix XI).

Additional statistics were carried out to find out more about the smoothness of movement. For this purpose, the data was divided into two groups: “smooth” and “not smooth” for each tests 3 and 4 separately. Descriptive statistics revealed that the “smooth” group reached higher general performance percentages than the “not smooth” group (table 26 in appendix XII) in both tests 3 and 4 and inferential statistics revealed that these differences were statistically significant ($P<0.05$; table 27 in appendix XII).

4. Discussion

4.1 Aim of this study

The main purpose of this cross-sectional experimental design research was to investigate the differences in the outcomes of the neuromuscular control tests with the Sensamove® therapy cushion in males and females aged 18 to 30 years. The secondary aim was to gain norm values for the Sensamove® therapy cushion NMC tests in 18 to 30 year-old healthy adults.

4.2 Summary of results

Although women reached higher scores on most tests and men had larger deviations than women, there were no statistically significant differences between 18 to 30 year-old males and females in the outcomes of the Sensamove® therapy cushion NMC tests.

Besides, no correlation was found between weight, height or hip circumference and the general performance in the NMC tests.

Norm values were established and an order of difficulty between exercises could be set (with exception of test 5 -dynamic cross-diagonal balance test-).

The smoothness of movement outcome variable, which indicates how much control and ease the participants showed while performing the tests, turned out to be the outcome variable revealing the most gender differences. Women performed sideways movements more smoothly than men, whereas men performed forward and backward movements more smoothly than women. Participants who performed smoothly also reached higher general performance percentages.

4.3 Comparison with other studies

Initially, the idea that gender differences could be found in the outcomes of the therapy cushion Sensamove® NMC tests came about because of the marked anatomical differences between men and women in the pelvic area[(11)(17)]. It seems that these differences do not affect sitting balance skills.

The hip circumference of male participants was bigger on average than that of female participants, which suggests that the population may not have been very representative with regards to hip circumference. Although no reference values could be found about gender-specific hip circumference, studies about the size of hip circumference as a predicting factor for cardiovascular diseases suggest that men have narrower hips than women[27]. In any case, the male group of the present study, which had statistically significant wider hips than the female group, and consequently a bigger base of support (BOS), did not have statistically significant better general performance percentages, so it can be inferred that wider hips do not affect the overall scores of the NMC tests.

The study by Vereeck L et al[28] suggests that although women of fifty years of age and over seem to have poorer balance in standing than men, gender does not have a statistically significant effect on standing balance in younger people. Menegoni F et al[29] also did research on standing balance in view of detecting gender differences, but this time, the population was obese. Besides the fact that obesity had a negative impact on balance skills, obese male were found to have significantly worse balance skills in a medio-lateral axis than obese women. Although these studies support the results found in the current research, they cannot be directly compared because the balance tests were done in standing position. No gender-based difference study was found on sitting balance.

Concerning the general performance of the total group, the overall scores of the Sensamove® NMC tests in sitting position with a therapy cushion were a lot higher than the overall scores provided by the test-retest reliability study on the Sensamove® NMC tests in standing position with a miniboard[25]. One reason for this might be that the center of pressure (COP) is further away from the base of support (BOS) in standing than it is in sitting, which makes it more difficult to maintain balance[30].

The Sensamove® therapy cushion was created with the idea that in addition to being a postural training tool, it could be a motivational tool for people with low balance skills[4]. The fact that the therapy cushion is used in sitting, which is less demanding than standing[30], and the fact that the therapy cushion in combination with the Sensamove® NMC tests has a playful aspect, could increase adherence to the training. The motivational aspect of playfulness in combination with balance tools has been suggested to increase adherence to training[25][31].

As it can be seen from the order of difficulty of the tests mentioned in the results section, the static balance test with visual feedback was the easiest test. Two factors seem to have made that test the easiest of all: the fact that the test was performed with eyes open and the fact that it was a static test. Davlin-Pater C[32] studied the effects of five different vision conditions on the static and dynamic sitting balance of 50 participants: 25 field-dependent (FD) participants (individuals who tend to rely more on their visual environment for balance perception) and 25 field-independent (FI) participants (individuals who tend to rely more on internal vestibular and somatosensory cues for balance perception). Both groups maintained better balance when visual feedback was present. Dynamic balance tasks were more difficult than static ones, because they demanded constant adjustments in body position. The FI

group was significantly more able to maintain balance during dynamic balance tasks, which was explained by the fact that dynamic balance generated more vestibular and somatosensory cues.

4.4 Additional remarks about results

No specific speed was imposed on the participants during the testing. This parameter was left to the participants' discretion. During testing, it was observed that participants performed at very different speeds. However, average speeds for tests 3 and 4 hardly differed between male and female and did not affect the general performance of the NMC tests, which suggests that speed does not affect the outcomes at all. In any case, a reason for this might be that the NMC tests in this study, which were designed to last one minute each only, may not have lasted long enough for differences to be detected. Speed may be an interesting variable to use in training sessions using the Sensamove® therapy cushion with interactive training software NMC.

4.5 Limitations of this study

Limitation linked to the population group:

The population group was made up of students, many of whom were physically active people who do sports in their free time. This could imply that the balance skills of the participants was better than those of average 18 to 30 year-olds.

Limitations associated with how the testing was performed

The 112 participants were measured by two researchers. Both researchers agreed to give the same instructions and measure participants in the same way. Nevertheless the fact that two different persons conducted the experiment might have induced differences in the performance of participants.

Besides, during the NMC tests, some participants compensated in order to reach higher scores. The following two types of compensations took place during the NMC tests:

-*Upper body*: some participants used their entire upper trunk during dynamic NMC tests while others used only their pelvic area. For instance when doing the left-right NMC test, some participants would move their entire upper body from left to right along with the pelvis.

-*Legs*: some participants used their legs during dynamic NMC tests while others kept them still. For instance when performing the left-right NMC test, some would move their legs from left to right along with the pelvis.

When researchers remarked compensation behaviours, they asked participants to try using their pelvic area more. Researchers observed that some participants were not capable of dissociating their pelvis from other parts of the body (upper body or legs or both). Researchers did not note down which

participants used more their hips and those who used more their upper body so it could not be concluded whether this affected the tests results or not.

Limitations associated with the settings of the software:

Before the start of each test, calibration was set. Researchers took care to perfectly calibrate but small deviations could not be avoided.

When setting up the Sensamove® therapy cushion, researchers faced a limit in how sensitive they could make the NMC test 1. During this test, the user needed to sit still on the cushion for 1 minute, it was decided that the sensitivity (which allows for small movements to be detected) would be high in order to make the test more difficult. However, whenever the sensitivity was set at a maximum and no one was sitting on the cushion, movements would still be detected as if the cushion was moving. Therefore, researchers couldn't set the sensitivity to a maximum; they were obliged to make the test less sensitive than intended. If test 1 could have been set more finely, perhaps the results would have shown more differences between participants.

For test 7, the user was asked to make small controlled movements within a circle shape. The circle shape is meant to be off-centre in order to see how the participant is able to cope with having to maintain balance in an off-centred position. The researchers misunderstood the aim of the test and set the circle shape in the centre, which means no data was collected about balance skills in an off-centred position.

4.6 Strengths of this study

This research provides the first study ever made about the Sensamove® therapy cushion with interactive training software NMC. The number of participants (112) taking part in this study was quite extensive, enabling the creation of norm values.

The fact that the tests were quite numerous (seven) and were varied (static, dynamic, open eyes, closed eyes) gave a good overview on the balance skills of the user. As well as which, both researchers assiduously stuck to the protocol during the experiment. Efforts were made to find settings for the experiment which would be sufficiently challenging.

4.7 Implications

The limitations faced in this research can help improve the Sensamove® interactive training software NMC and help in the guidance of future research about the Sensamove® therapy cushion NMC tests.

This study offers norm values for young adults aged 18 to 30 years using the Sensamove® therapy cushion with interactive training software NMC. It has shown that no differentiation seems to be necessary between male norm values and female norm values. Instead, the norm values for the total group may be used.

These norm values may be used to test the sitting balance skills of 18 to 30 year-old people. Nevertheless care must be taken regarding the interpretation of the outcomes because no validity or reliability study has been done on the NMC tests in combination with the Sensamove® therapy cushion.

Low back pain is a very common musculoskeletal condition[1] and there is strong evidence that physiotherapy is effective in the treatment of this condition[33]. Exercise therapy is beneficial for patients with chronic low back pain[33] and since these patients have impaired postural control[34], it is important to find the most effective ways to train postural control[2]. The Sensamove® therapy cushion seems to be a promising tool for training postural control in people with low back pain and trunk postural deficits and it would merit further research with a view to use in clinical practice. Besides, the playful aspect of the Sensamove® therapy cushion with interactive training software NMC could turn a boring postural training into fun!

In order to further promote the Sensamove® therapy cushion and the NMC tests in widespread clinical practice, more research must be done on the validity and reliability of these tools. Further research is necessary to investigate the Sensamove® therapy cushion as a training tool and the effects of variables such as speed and smoothness of movement. The compensations from the upper body and legs, which sometimes take place during the use of the Sensamove® therapy cushion may also be a relevant topic to look into. It might be of interest to carry out studies on the improvement of sitting balance skills with the use of the Sensamove® therapy cushion over a period of time.

4.8 Conclusion

No statistically significant difference was found between 18 to 30 year-old males and females in the outcomes of the Sensamove® therapy cushion NMC tests, no matter whether weight, height or hip circumference differed. The Sensamove® therapy cushion NMC tests norm values for 18 to 30 year-old, established in this study, can be used for testing and training purposes, but care must be taken when it comes to interpreting results. Further research may clarify the interpretation of Sensamove® therapy cushion NMC tests.

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6. Appendices

Appendix I: Information letter

Graduation research projects

"The Sensamove® Therapy Cushion – a promising therapy tool of the 21st century?"

"Gender specific outcomes of the Neuromuscular Control tests with the Sensamove® therapy cushion"

Dear students,

Thank you ever so much for showing interest in our study. You will hereby find all necessary information about our research project and discover whether or not you are suited to participate in it. Please take the time to read this letter carefully. We will be delighted to answer any questions you might have concerning this research project.

What is the purpose of this research?

During activities of daily life of a human being, balance skills are solicited. Many of the activities we undertake require static or dynamic postural control. Any impairment affecting our sense of balance will greatly affect our lives. Therefore it is very important to detect these impairments and work on them so that they don't take over our lives and stop us from performing daily tasks. It is one of the roles of physiotherapists to detect, help prevent, and cure balance and postural related problems. For this, physiotherapists use many tools such as Swiss balls, balance boards, therapy cushions…

In this study, we focus on one of these tools, the Sensamove® therapy cushion. This air filled cushion is embedded with a sensor, which is connected to a computer and detects movement. A software on the computer translates the information received by the cushion and provides feedback of pelvis tilt and consequent spine erection and lumbar lordosis or kyphosis, therefore promoting postural learning. This cushion can hence be used for diagnosing or training.

Sensamove® developed different tests and games on the software to be used. This study will carry out some of these, namely the "NMC tests – Neuromuscular Control tests". These are a series of seven tests challenging balance, proprioception and core stability.

The Sensamove® therapy cushion along with its software are a relatively recent invention and no norm values have yet been established to determine whether the feedback results give any indication about wrong posture, lack of stability/proprioception or balance deficits. The aim of this study is to find out how 18 to 30 year old healthy adults perform on the Sensamove® therapy cushion NMC tests. While Sinéad Nora McAleer will assess the differences in male and female in performance, Simon

Masoner will conduct a research on how body fat percentage and activity levels may affect the outcomes.

Respectively taking part in this experiment means that you will be involved in two different research projects: The one of Sinéad McAleer and the other of Simon Masoner.

What is happening during the research?

Once you decide to take part in this research, a date and time will be set for the experiment. Upon arrival in the experiment room, you will kindly be asked to sign an informed consent. You will be given a brief introduction about the experimental procedure and you will be given the possibility to ask questions. Your personal details (name, age, gender…) will be gathered and your weight, height, hip circumference and body fat percentage will be measured and recorded. In order to measure your hip circumference, you will be asked to lower your trousers a little bit. To get information about your Level of Physical Activity you need to fill out the International Physical Activity Questionnaire (IPAQ-short version). You will then be given a sheet of paper with a series of seven numbers determining the order in which you will perform the seven NMC tests. You will then be instructed to sit on the therapy cushion. A one-minute trial will take place for you to get a feel for the cushion, before the actual experiment begins.

Who can participate in the research?

- Young healthy adults, aged between 18-30 years old
- No known specific back problems
- No serious medical condition (cardiovascular-, neurological disorders)
- No current medical condition impairing performance (fever, cold, headache, dizziness, feeling of sickness…)
- No diagnosed balance disorder (vestibular organ dysfunction, benign paroxysmal positional vertigo -BPPV-…)
- No previous injury or surgery on the back, spine, pelvic or abdominal area over the past six months
- No visual impairment that cannot be corrected with glasses
- Not use of medication affecting balance or vision
- No high intensity core training previously to testing on the same day
- No women currently having their periods*
- No pregnant women or women having already gave birth

* The date of the experiment can be set to fit this criteria.

What are advantages and/or disadvantages of participating?

Apart from the fact that the experiment will take 30 minutes of your time and that you will have to travel to the experiment room independently, there will be no disadvantages for you. There are no potential risks known and taking part in the study will give you the following advantages:

- You will experience an innovative physiotherapeutic tool which withholds an element of fun
- If you are undergoing bachelor studies, you will be given an insight on how to conduct an experimental study.

When and where does the experiment take place?

Time: 19/10/2015 – 13/11/2015 between 09:00-17:00

The experiment will last 30 minutes.

Once you decide to take part in our study, you will be given an exact time for the experiment.

The experiment will take place in the "Health Check" room of Fontys University of Applied Sciences, located at Dominee Theodor de Fliednestraat 2, 5600AH Eindhoven.

What happens with the data?

The data you will provide us with, will be handled anonymously and with care so that it cannot be traced back to you. The measured data will be used for the research of Sinéad Nora McAleer and the research of Simon Masoner.

Please do not hesitate to contact us for further information about this study.
We would be ever so grateful if you could get in touch with us, preferably via webmail, as soon as possible when you have decided if you will take part in our research project or not. Please let us know latest on 18th October 2015.
We hope to hear from you soon.

Kind regards,

Sinéad Nora McAleer and Simon Masoner

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Appendix II: Information letter in Dutch – Informatiebrief

Afstudeerscriptie

"The Sensamove® Therapy Cushion – a promising therapy tool of the 21st century?"

"Gender specific outcomes of the Neuromuscular Control tests with the Sensamove® therapy cushion"

Beste deelnemer,

Heel erg bedankt dat je zoveel interesse toont in ons onderzoek. Bij deze krijg je alle nodige informatie over ons onderzoeksproject zodat je zelf kunt besluiten of je wel of niet deelneemt. Neem a.u.b. rustig de tijd om deze brief aandachtig te lezen. We beantwoorden graag al jullie vragen over het onderzoek.

Wat is het doel van dit onderzoek?

Tijdens algemeen dagelijks levensactiviteiten van een persoon wordt aanspraak gemaakt op evenwichtsvaardigheden. Veel van de activiteiten die wij ondernemen veronderstellen statische of dynamische houdingscontrole. Een beperking van ons evenwichtsgevoel heeft grote gevolgen. Daarom is het belangrijk om zulke beperkingen te identificeren en te verhelpen zodat ze ons niet meer in de weg staan tijdens alledaagse activiteiten. Het is een van de verantwoordelijkheden van de fysiotherapeut om evenwichts- en houdingsgerelateerde op te sporen en te voorkomen. Voor dit doeleinde benutten fysiotherapeuten verschillende hulpmiddelen zoals de Swiss ball, balance boards en evenwichtskussens.

In deze studie richten we ons op een van deze instrumenten, het Sensamove® therapy kussen. Het kussen is gevuld met lucht en bevat een sensor, die in verbinding staat met een computer en beweging detecteert. De software op de computer vertaalt de door het kussengeregistreerde informatie en geeft vervolgens feedback betreffende de bekkenstand en de mate van lumbale lordose/kyfose. Het kussen kan dus zowel diagnostisch als therapeutisch worden ingezet.

Sensamove® heeft in hun software verschillende tests en spelletjes meegeleverd. Deze studie zal een deel hiervan benutten, namelijk de "NMC tests – Neuromuscular Control". Dit is een reeks van zeven tests betreffende evenwicht, proprioceptie en rompstabiliteit.

Het Sensamove® therapy kussen met software is een relatief nieuwe uitvinding en er zijn tot op heden nog geen normwaarden vastgesteld om vast te stellen of de feedback enige indicatie geeft over houdingsafwijkingen en gebrekkige stabiliteit, evenwicht en proprioceptie. Het doel van deze studie is om normwaarden verkrijgen voor bovengenoemde NMC tests van gezonde volwassenen tussen de 18 en 30 jaar oud.

Sinéad Nora McAleer score zal in haar studie verschillen vergelijken tussen testresultaten van mannen en vrouwen, terwijl Simon Masoner gaat onderzoeken hoe lichaamsvetpercentage en activiteitenniveau de resultaten beinvloeden.

Deelname aan dit experiment betekent dus dat je testresultaten in beide studies worden gebruikt.

Wat gebeurt er precies tijdens het experiment?

Zodra je besluit deel te nemen zullen een datum en tijd worden vastgesteld. Bij aankomst in de onderzoeksruimte, zal je worden gevraagd om een toestemmingsverklaringformulier te tekenen. Vervolgens krijg je een korte introductie betreffende de procedure en is er gelegenheid om vragen te stellen. Je persoonsgegevens zullen worden verzameld (naam, leeftijd, geslacht) en je gewicht, lengte, heupbreedte en lichaamsvetpercentage zullen worden gemeten en geregistreerd. Om een beeld te krijgen over je activiteitenniveau zullen we je vragen een vragenlijst in te vullen, namelijk het “International Physical Activity Questionnaire (IPAQ)”. Vervolgens krijg je een blad waarop een willekeurige volgorde van de 7 tests staat vermeld. Daarna zal je worden geïnstrueerd op het Sensamove® therapy kussen te gaan zitten en zal het experiment beginnen.

Wie kan deelnemen in dit onderzoek?

- Gezonde jongvolwassenen van 18-30 jaar oud.
- Afwezigheid van specifieke rugklachten
- Geen ernstige gezondheidsproblemen (cardiovasculaire of neurologische problematiek)
- Op de dag van testen dienen er geen gezondheidsproblemen te zijn die je prestatie kunnen beïnvloeden. (koorts, verkoudheid, hoofdpijn, duizeligheid, algeheel onwelbevinden)
- Geen medisch vastgestelde evenwichtsproblematiek (dysfunctionerend evenwichtsorgaan, goedaardige paroxysmale positionele vertigo)
- Geen eerdere operaties of trauma's van wervelkolom, bekken of buik gedurende de afgelopen 6 maanden.
- Geen visuele beperkingen die niet m.b.v. bril kunnen worden gecorrigeerd.
- Geen gebruik van medicatie die mogelijk een verstorende werking hebben op evenwicht of gezichtsvermogen.
- Voorafgaand aan het experiment geen intensieve training van de romp (op de testdag zelf)
- De test dient geen plaats te vinden op een dag dat je ongesteld bent.*
- Geen zwangerschap in het heden of verleden.

* Hier kan natuurlijk rekening mee worden gehouden bij het kiezen van de testdatum.

Wat zijn voordelen en/of nadelen van deelname?

Naast het feit dat het experiment 30 minuten van je tijd in beslag neemt en dat we je vragen zelf naar de onderzoeksruimte te komen, zal je geen nadelen ondervinden. Het onderzoek brengt geen risico's met zich mee. Deelname levert je de volgende voordelen op:

- Je doet een interessante en leuke ervaring op met een innovatief fysiotherapeutisch instrument.
- Indien je zelf een bachelor studie volgt vergaar je inzicht in het uitvoeren van een experimenteel onderzoek.

Wanneer en waar vindt het experiment plaats?

Tijd: 19/10/2015 – 13/11/2015 tussen 09:00-17:00

Het experiment duurt 30 minuten.

Zodra je besluit deel te nemen zal een precies tijdstip met je worden afgestemd.

Locatie is in het “Health Lab” (rechts van de receptie bij de hoofdingang) op de Fontys Paramedische Hogeschool, Dominee Theodor Fliednerstraat 2, 5600AH Eindhoven.

Wat gebeurt er met de verzamelde data?

De data die voortkomt uit jouw tests, zal volstrekt anoniem en vertrouwelijk worden behandeld zodat geen van de data naar jouw kunnen worden herleid. Data zal zowel worden gebruikt voor het onderzoak van Sinéad Nora McAleer als dat van Simon Masoner.

Aarzal niet om contact op te nemen voor meer informatie over dit onderzoek.

Als je besluit om deel te nemen aan dit experiment zouden we je erg dankbaar zijn als je ons hier zo snel mogelijk over informeert. Graag horen we ten laatste 18 oktober 2015 van je.

Hopelijk tot snel.
Met vriendelijke groet

Sinéad Nora McAleer and Simon Masoner

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Appendix III: Invitation letter

Dear students,

As you may already know, the 4th graders are currently working on their Bachelor Thesis and perform different experimental researches.

We, Sinead Nora McAleer and Simon Masoner are conducting a research project about an innovative Physiotherapy tool called “Sensamove® Therapy Cushion”. In this research, we want to gather data about the performance of a series of seven different tests challenging your balance, proprioception and core stability.

It is a nice project to take part in, because it is a good way to get to know another Physiotherapeutic treatment and testing tool. Moreover, no one has ever performed a research on this topic before. Furthermore it is also a little preparation for your own thesis project.

There are no risks involved in the experiment and it will just take half an hour of your time.

The testing will start in the week of 19th October and will last till 13th of November. You would help us a lot if you could come by on one of these days and we will do our best to be as flexible as possible to find a matching time for you.

If you are interested in taking part in this study, please read the information letter attached to this mail and let us know when you want to come by.

We are looking forward to see you in our study and want to invite you to contact us if you have any questions about it.

Greetings,

Sinead Nora McAleer and Simon Masoner

Researchers:

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Appendix IV: Invitation letter in Dutch

Uitnodiging:

Beste studenten,

Zoals jullie weten werken de vierdejaars momenteel aan hun Bachelor Thesis en voeren hiervoor verschillende experimenten uit.

Wij, Sinead Nora McAleer and Simon Masoner zijn momenteel bezig met een onderzoeksproject over een innovatief fysiotherapeutisch instrument, genaamd “Sensamove® Therapy Cushion”. In dit onderzoek willen we data verzamelen over de scores van zeven verschillende test m.b.t. balans, proprioceptie en rompstabiliteit.

Het experiment is risicovrij en zal slechts een half uur van je tijd in beslag nemen.

De tests zullen plaatsvinden van 19 oktober tot 13 november. Het zou voor ons een grote meerwaarde zijn als je in deze periode langs zou kunnen komen en wij zullen ons uiterste best doen om een voor jouw passend tijdstip te vinden.

Als je overweegt om deel te nemen in deze studie, lees dan a.u.b. de informatiebrief bijgevoegd in deze mail en laat ons weten wanneer je graag langs zou komen.

We kijken er naar uit je te zien tijdens ons experiment en nodigen je uit contact met ons op te nemen als je nog vragen hebt.

Groetjes,

Sinead Nora McAleer and Simon Masoner

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Appendix V: Informed Consent

Participation agreement in the two studies:

1. "*What is the correlation between the NMC tests measured with the Sensamove® Therapy Cushion, body fat percentage and level of physical activity in 18 to 30 years old healthy adults?* "

2. "What are the possible differences in the outcomes of the Sensamove® Therapy Cushion NMC tests between 18 to 30 years old healthy men compared to 18 to 30 years old healthy women?"

Herewith I declare that I agree with the following statements:

- I have read the information letter and was able to post any possible questions and got them answered. I feel myself fully informed about the testing procedure and possible dangerous situation.
- I had enough time to think about my participation. I declare that my participation is completely voluntarily. I know that I can withdraw my participation at any time without giving a reason why.
- I agree that in the highly unlikely case of an injury the conductor of this research cannot be hold responsible.
- I agree that my personal data will be applicable to the researchers, the supervisor and the CEO of Sensamove®. Results may be published for scientific purposes but will not give your name or any other identifiable references. If you wish to receive your results after the testing, please tick the box below. Your name will then be listed separately and confidentially with a reference to your data. This list will be destroyed upon completion of the study.

- I agree to participate in the research.

Name test person: ☐ I want to receive my test results after the research is finished

Signature: Date: __/__/__ (DD/MM/YY)

- I herewith declare that I have fully informed the participating people about the testing procedure.

- In the unlikely case that there should be anything that could change the participation agreement I will inform the affected people in time.

Simon Masoner (Researcher) Sinéad Nora McAleer (Researcher)

Date: __/__/__ (DD/MM/YY)

Appendix VI: Informed Consent in Dutch - Toestemmingsverklaring

Deelname overeenkomst voor de volgende twee studies

1. "*What is the correlation between the NMC tests measured with the Sensamove® Therapy Cushion, body fat percentage and level of physical activity in 18 to 30 years old healthy adults?* "

2. "What are the possible differences in the outcomes of the Sensamove® Therapy Cushion NMC tests between 18 to 30 years old healthy men compared to 18 to 30 years old healthy women?"

Ik verklaar bij deze dat de volgende regels op mij van toepassing zijn:

- Ik heb de informatiebrief gelezen en ben in de gelegenheid geweest hier vragen over te stellen. Ik beschouw mijzelf als volledig geïnformeerd betreffende de testprocedure en mogelijke risico's.
- Ik heb voldoende tijd gehad om mijn eventuele deelname te overwegen. Ik verklaar enkel op vrijwillige basis deel te nemen. Ik ben mij ervan bewust dat ik mijn deelname op elk gegeven tijdstip kan stopzetten, zonder dat hiervoor een reden zal worden gevraagd.
- Ik ga ermee akkoord dat de onderzoekers niet verantwoordelijk kunnen worden gehouden voor fysiek letsel dat in een hoogst onwaarschijnlijk geval zou optreden.
- Ik ga ermee akkoord dat mijn persoonlijke data die tijdens het onderzoek worden verzameld, toegankelijk zijn voor de in deze brief genoemde personen. Resultaten kunnen worden gepubliceerd maar zullen geen enkele verwijzing bevatten naar een specifiek persoon. Als je graag na afloop van het onderzoek je persoonlijke resultaten ontvangt, vink dan onderstaand hokje aan. Je naam wordt dan apart en vertrouwelijk geregistreerd met een referentie naar jouw data. Deze lijst zal worden vernietigd bij afloop van de studie.
- Ik wil graag deelnemen aan deze studie.

Naam proefpersoon: Ik ontvang graag mijn testresultaten na afloop van het onderzoek.

Handtekening: Datum: __/__/__ (DD/MM/YY)

- Ik verklaar bij deze de deelnemende personen volledig te hebben geïnformeerd over de testprocedure.
- In het onwaarschijnlijke geval dat er iets in deze verklaring zou veranderen, zal ik de betrokken personen hier tijdig over informeren.

Simon Masoner (Onderzoeker) Sinéad Nora McAleer (Onderzoeker)

Date: __/__/__ (DD/MM/YY)

Appendix VII: Weight/Height measurement protocol

Weight/Height Scale:

- The participant receives a testing number
- The reasearcher activates the machine with the testing number
- The participant takes off his/her shoes, socks, pullover, jacket and any metall items (jewelry, belt…)
- The participant steps onto the machine and remains still until the machine measured weight and height

Appendix VIII: Protocol for the experiment

Setting of the equipment:

- Support for the therapy cushion: a stool is used under the cushion. The stool does not spin and the height is adjustable. The stool has a completely flat surface and no back support.
- Support for the computer providing feedback:
    - The computer is placed on a table 75cm away from the stool
    - The screen is placed in front of the participant, straight ahead and level with the eyes of the participant
    - In order to keep the exact same measurements for each participant, tape is placed on the floor, marking the position of the stool and computer by a cross.

Setting of the software:

Table 9: Software settings

	Max tilting	Shape size	Shape width	Radius	Position from the center	Radial position	Duration
Test 1	5	-	-	-	-	-	60s
Test 2	5	-	-	-	-	-	60s
Test 3	5	10	1	-	-	-	60s
Test 4	5	10	1	-	-	-	60s
Test 5	5	10	1	-	-	-	60s
Test 6	5	-	1	2	-	-	60s
Test 7	5	-	1	-	0	0	60s

- : no settings

s : seconds

1: Static balance test; 2: Static balance test without visual feedback; 3: Dynamic left-right balance test; 4: Dynamic front-back balance test; 5: Dynamic cross-diagonal balance test; 6: Dynamic donut balance test; 7: Dynamic circle balance test

Setting of the subject:

The participant must sit down as follows:

- Shoes off
- Flat feet on the floor
- Knees and hip at a 90 degrees angle
- Straight back: no slouching or increased lordosis
- Looking at the screen

Instructions:

Prior to testing, instructions are given on the following topics:

- Position of the participant
- Calibration x2

During the tests, no verbal exchange takes place between author and participant. In between tests, instructions about the following test and posture are given.

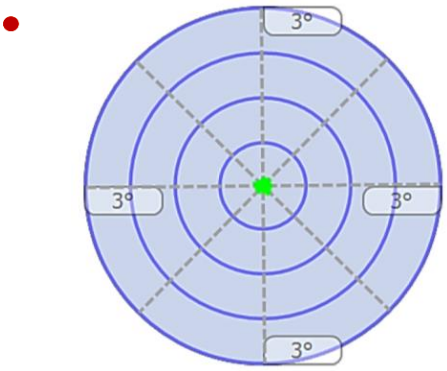
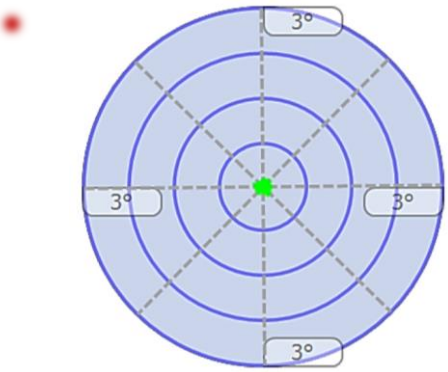
Pre Trial:

Participant can try out the Sensamove cushion for 1 minute.

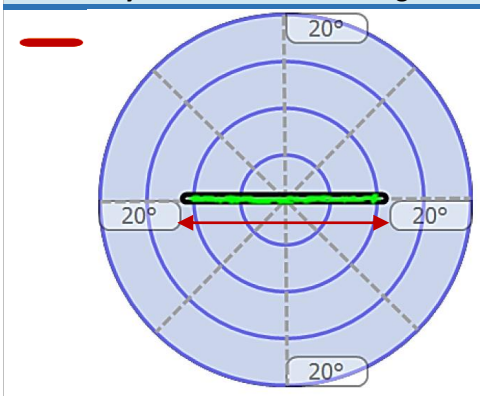
Procedure of the NMC test:

The NMC test will last 15 minutes. The 7 tests will be performed in a random order using the random integer set generator RANDOM.ORG[20]. 120 sets will be requested, with 7 unique random integers in each, taken from the [1,7] range. The integers in each set will not be sorted (Appendix IX).

For each test, the participant starts in the center. Before the start of each separate test, calibration will be done and instructions are given.

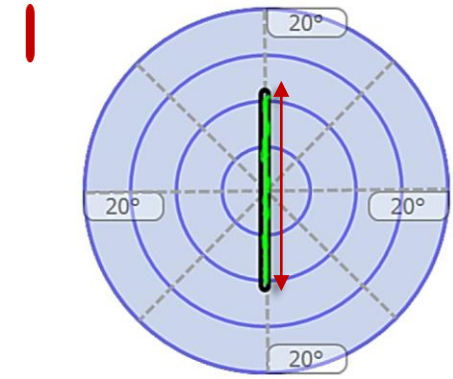
Test 1: Static Balance	
	- The participant is asked to sit still wih his eyes open, trying to keep the red dot in the center - Duration: 1 min
Test 2: Static Balance –proprioception	
	- The participant is asked to sit still with his eyes closed, trying to keep the red dot in the center - Duration: 1 min

Test 3: Dynamic Balance- left-right



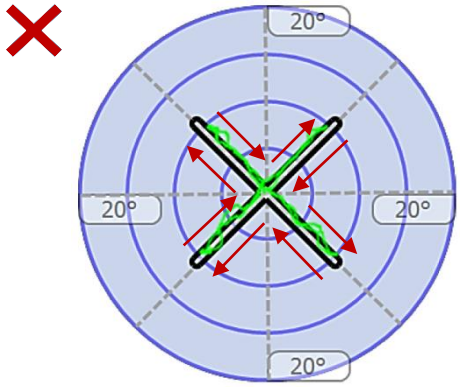
- The participant is asked the move the red dot from side to side, trying to stay between the lines
- Duration: 1 min

Test 4: Dynamic Balance- front-back



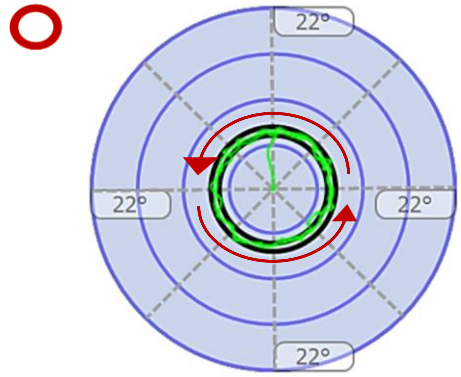
- The participant is asked the move his pelvis forwards and backwards, trying to stay between the lines
- Duration: 1 min

Test 5: Dynamic Balance – cross diagonal



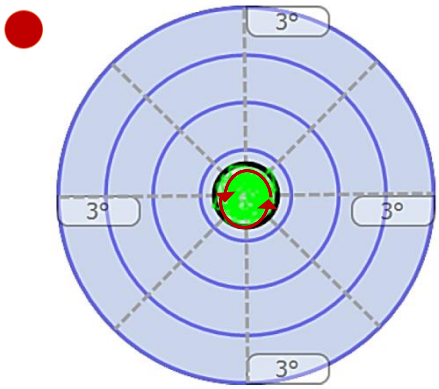
- The participant is asked the move the red dot in a cross manner, trying to stay between the lines. He is asked to go to one end of the cross, back to the center the next and then to the end of the next cross, etc.
- Duration: 1 min

Test 6: Dynamic Balance - donut



- The participant is asked to move the red dot around the donut, trying to stay between the lines.
- Duration: 1 min

Test 7: Dynamic Balance- circle



- The participant is asked to move the red dot in small circles during, trying to stay inside the circle.
- Duration: 1 min

Appendix IX: Random sets

Table 10: Random sets

Subject Number	Sequence
1	2 5 1 7 3 4 6
2	7 6 2 3 4 1 5
3	1 3 6 2 5 7 4
4	5 7 3 1 2 6 4
5	1 3 6 7 4 5 2
6	6 1 3 7 2 4 5
7	4 2 1 6 3 7 5
8	3 6 2 1 4 7 5
9	3 2 7 5 6 1 4
10	7 1 6 3 4 2 5
11	5 6 1 4 3 7 2
12	5 3 6 7 1 2 4
13	6 1 2 5 3 4 7
14	2 1 6 3 4 5 7
15	2 4 6 7 5 3 1
16	6 3 2 4 1 5 7
17	4 3 5 2 6 1 7
18	6 7 1 4 5 2 3
19	6 2 7 5 1 4 3
20	7 3 5 4 2 6 1
21	2 3 5 1 4 7 6
22	7 2 5 3 4 1 6
23	3 6 7 1 5 2 4
24	7 3 5 6 4 2 1

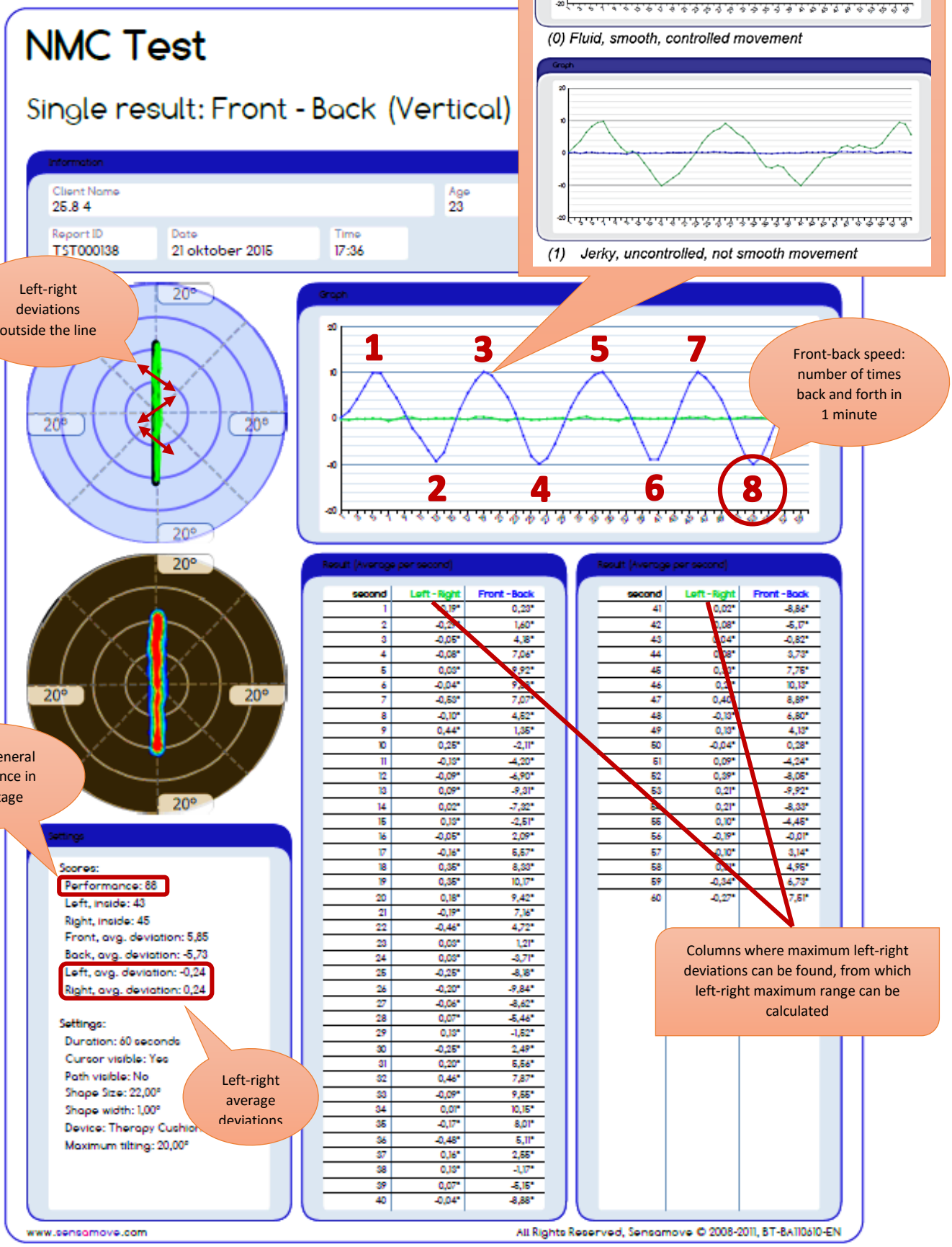
25	6 7 2 5 1 3 4
26	7 5 6 1 2 4 3
27	3 6 4 5 1 2 7
28	6 3 5 1 7 4 2
29	2 5 1 3 6 7 4
30	6 7 2 3 5 4 1
31	7 4 6 2 5 3 1
32	3 2 6 5 4 1 7
33	2 5 6 7 3 4 1
34	5 4 3 7 6 1 2
35	1 4 5 3 6 2 7
36	3 5 1 2 7 6 4
37	6 5 3 4 1 7 2
38	6 2 3 4 1 5 7
39	3 2 4 7 6 1 5
40	1 3 5 2 6 4 7
41	3 6 2 4 5 7 1
42	6 2 3 1 4 5 7
43	4 6 3 2 1 5 7
44	1 2 4 3 5 7 6
45	6 4 1 2 7 5 3
46	6 4 2 1 5 7 3
47	1 5 3 4 2 6 7
48	6 7 5 3 2 1 4
49	1 2 3 4 7 6 5
50	2 6 1 5 4 7 3
51	4 5 2 6 7 1 3

52	5 3 1 2 6 7 4
53	3 6 4 5 2 1 7
54	7 4 3 2 5 1 6
55	6 3 5 4 2 1 7
56	5 3 7 6 2 1 4
57	4 7 3 2 1 6 5
58	6 3 1 7 5 2 4
59	7 2 1 6 4 3 5
60	7 2 6 1 4 5 3
61	7 2 5 3 6 1 4
62	7 1 2 3 6 5 4
63	7 1 3 5 4 6 2
64	1 4 6 3 7 5 2
65	7 5 2 4 1 3 6
66	6 1 4 7 3 2 5
67	6 1 5 7 4 3 2
68	1 2 5 3 6 4 7
69	5 6 3 1 4 2 7
70	5 3 7 4 2 1 6
71	7 2 4 3 5 1 6
72	4 7 1 3 5 2 6
73	5 3 7 1 6 4 2
74	1 6 3 2 7 5 4
75	2 4 6 7 3 5 1
76	1 3 5 4 7 2 6
77	3 1 2 7 6 4 5
78	7 5 6 1 2 4 3

79	4 3 1 5 7 6 2
80	4 7 6 5 2 3 1
81	7 3 1 6 4 2 5
82	7 3 1 6 5 2 4
83	4 6 5 3 1 2 7
84	6 7 4 1 2 3 5
85	4 7 3 1 5 2 6
86	7 2 6 5 1 3 4
87	4 2 1 5 7 3 6
88	4 1 5 3 7 2 6
89	7 2 3 6 5 4 1
90	7 3 2 4 6 5 1
91	2 6 3 7 5 4 1
92	4 1 2 7 3 5 6
93	1 6 5 2 4 7 3
94	4 3 2 1 5 7 6
95	2 4 6 7 5 3 1
96	2 3 1 7 5 6 4
97	2 4 6 5 3 1 7
98	7 1 5 3 4 6 2
99	6 7 5 4 3 2 1
100	2 1 5 3 7 6 4
101	7 5 4 1 3 6 2
102	1 3 4 6 5 2 7
103	3 4 2 7 6 5 1
104	4 2 1 7 3 6 5
105	1 4 7 5 6 2 3

106	5 6 3 2 4 1 7
107	1 6 2 5 7 4 3
108	6 2 4 1 5 3 7
109	3 4 1 6 7 2 5
110	2 5 1 6 3 7 4
111	3 6 1 4 7 2 5
112	5 3 2 4 6 7 1
113	2 1 7 5 3 6 4
114	1 7 2 4 5 6 3
115	4 7 2 3 1 6 5
116	2 6 7 5 3 1 4
117	1 5 3 6 4 7 2
118	5 3 6 4 2 1 7
119	3 4 1 6 7 2 5
120	7 6 2 1 4 5 3

Appendix X: Example: Outcome PDF sheet for test 4



Appendix XI: Hypothesis

The following hypothesis will be tested.

Table 11: Tested hypothesis about the general performance outcome variable

Hypothesis a)	
H0:	Women and men have equal average percentages for the overall general performance in each separate Sensamove® therapy cushion 1. to 7.* NMC tests
H1:	Women have better average percentages than men for the overall general performance in each separate Sensamove® therapy cushion NMC 1. to 7.* tests
Hypothesis b)	
H0:	Women and men have equal average percentages for the overall general performance during the static balance test 1.* and the dynamic balance test 3* of the Sensamove® therapy cushion NMC tests
H1:	Women have better average percentages than men for the overall general performance in the static balance test 1.* than the dynamic balance test 3.* of the Sensamove® therapy cushion NMC tests
Hypothesis c)	
H0:	Women and men have equal average percentages for the overall general performance during the static balance test 1.* and the dynamic balance test 4* of the Sensamove® therapy cushion NMC tests
H1:	Women have better average percentages than men for the overall general performance in the static balance test 1.* than the dynamic balance test 4.* of the Sensamove® therapy cushion NMC tests
Hypothesis d)	
H0:	Women and men have equal average percentages for the overall general performance during the static balance test 1.* and the dynamic balance test 5* of the Sensamove® therapy cushion NMC tests
H1:	Women have better average percentages than men for the overall general performance in the static balance test 1.* than the dynamic balance test 5.* of the Sensamove® therapy cushion NMC tests
Hypothesis e)	
H0:	Women and men have equal average percentages for the overall general performance during the static balance test 1.* and the dynamic balance test 6* of the Sensamove® therapy cushion NMC tests
H1:	Women have better average percentages than men for the overall general performance in the static balance test 1.* than the dynamic balance test 6.* of the Sensamove® therapy cushion NMC tests
Hypothesis f)	
H0:	Women and men have equal average percentages for the overall general performance during the static balance test 1.* and the dynamic balance test 7* of the Sensamove® therapy cushion NMC tests
H1:	Women have better average percentages than men for the overall general performance in the static balance test 1.* than the dynamic balance test 7.* of the Sensamove® therapy cushion NMC tests
Hypothesis g)	
H0:	Women and men have equal average percentages for the overall general performance during the static open eyes balance test 1.* and the static closed eyes balance test 2* of the Sensamove® therapy cushion NMC tests
H1:	Women have better average percentages than men for the overall general performance in the static open eyes balance test 1.* than the static closed eyes balance test 2.* of the Sensamove® therapy cushion NMC tests

*: see Appendix VIII

1: Static balance test; 2: Static balance test with eyes closed (proprioception); 3: Dynamic left-right balance test; 4: Dynamic front-back balance test; 5: Dynamic cross-diagonal balance test; 6: Dynamic donut balance test; 7: Dynamic circle balance test

Table 12: Tested hypothesis about the outcome variables - front/back/left/right average deviations and maximum deviations -

Hypothesis h)	
H0:	Women and men have equal front average deviations when performing the NMC test 3.* using the Sensamove® therapy cushion
H1:	Women and men have different front average deviations when performing the NMC test 3.* using the Sensamove® therapy cushion
Hypothesis i)	
H0:	Women and men have equal back average deviations when performing the NMC test 3.* using the Sensamove® therapy cushion
H1:	Women and men have different back average deviations when performing the NMC test 3.* using the Sensamove® therapy cushion
Hypothesis j)	
H0:	Women and men have equal left average deviations when performing the NMC test 4.* using the Sensamove® therapy cushion
H1:	Women and men have different left average deviations when performing the NMC test 4.* using the Sensamove® therapy cushion
Hypothesis k)	
H0:	Women and men have equal right average deviations when performing the NMC test 4.* using the Sensamove® therapy cushion
H1:	Women and men have different right average deviations when performing the NMC test 4.* using the Sensamove® therapy cushion
Hypothesis l)	
H0:	Women and men have equal front maximum deviations when performing the NMC test 3.* using the Sensamove® therapy cushion
H1:	Women and men have different front maximum deviations when performing the NMC test 3.* using the Sensamove® therapy cushion
Hypothesis m)	
H0:	Women and men have equal back maximum deviations when performing the NMC test 3.* using the Sensamove® therapy cushion
H1:	Women and men have different back maximum deviations when performing the NMC test 3.* using the Sensamove® therapy cushion
Hypothesis n)	
H0:	Women and men have equal left maximum deviations when performing the NMC test 4.* using the Sensamove® therapy cushion
H1:	Women and men have different left maximum deviations when performing the NMC test 3.* using the Sensamove® therapy cushion
Hypothesis o)	
H0:	Women and men have equal right maximum deviations when performing the NMC test 4.* using the Sensamove® therapy cushion
H1:	Women and men have different right maximum deviations when performing the NMC test 3.* using the Sensamove® therapy cushion

*: see Appendix VIII

1: Static balance test; 2: Static balance test with eyes closed (proprioception); 3: Dynamic left-right balance test; 4: Dynamic front-back balance test; 5: Dynamic cross-diagonal balance test; 6: Dynamic donut balance test; 7: Dynamic circle balance test

Table 13: Tested hypothesis about the outcome variables – front-back/left-right maximum ranges -

Hypothesis p)	
H0:	Women and men have equal front-back maximum ranges when performing the NMC test 3.* using the Sensamove® therapy cushion
H1:	Women and men have different front-back maximum ranges when performing the NMC test 3.* using the Sensamove® therapy cushion
Hypothesis q)	
H0:	Women and men have equal left-right maximum ranges when performing the NMC test 4.* using the Sensamove® therapy cushion
H1:	Women and men have different left-right maximum ranges when performing the NMC test 4.* using the Sensamove® therapy cushion

*: see Appendix VIII

1: Static balance test; 2: Static balance test with eyes closed (proprioception); 3: Dynamic left-right balance test; 4: Dynamic front-back balance test; 5: Dynamic cross-diagonal balance test; 6: Dynamic donut balance test; 7: Dynamic circle balance test

Table 14: Tested hypothesis about the outcome variables – front-back/left-right average speed -

Hypothesis r)	
H0:	Women and men have equal left-right average speed when performing the NMC test 3.* using the Sensamove® therapy cushion
H1:	Women and men have different left-right average speed when performing the NMC test 3.* using the Sensamove® therapy cushion
Hypothesis s)	
H0:	Women and men have equal front-back average speed when performing the NMC test 4.* using the Sensamove® therapy cushion
H1:	Women and men have different front-back average speed when performing the NMC test 4.* using the Sensamove® therapy cushion

*: see Appendix VIII

1: Static balance test; 2: Static balance test with eyes closed (proprioception); 3: Dynamic left-right balance test; 4: Dynamic front-back balance test; 5: Dynamic cross-diagonal balance test; 6: Dynamic donut balance test; 7: Dynamic circle balance test

Table 15: Tested hypothesis about the outcome variables – smoothness of front-back/left-right movements -

Hypothesis t)	
H0:	Women and men have an equal percentage of smooth left-right movement performances in the NMC test 3.* using the Sensamove® therapy cushion
H1:	Women have a better percentage of smooth left-right movement performances than men in the NMC test 3.* using the Sensamove® therapy cushion
Hypothesis u)	
H0:	Women and men have an equal percentage of smooth front-back movement performances in the NMC test 4.* using the Sensamove® therapy cushion
H1:	Women have a better percentage of smooth front-back movement performances than men in the NMC test 4.* using the Sensamove® therapy cushion

*: see Appendix VIII

1: Static balance test; 2: Static balance test with eyes closed (proprioception); 3: Dynamic left-right balance test; 4: Dynamic front-back balance test; 5: Dynamic cross-diagonal balance test; 6: Dynamic donut balance test; 7: Dynamic circle balance test

For each hypothesis where women are expected to perform better than men, if $P < 0.05$, the H0 is rejected and consequently, if women have a better score than men, H1 is accepted. In the case that $P > 0.05$, the H0 is accepted and consequently, H1 is rejected.

For each hypothesis where women and men are expected to perform differently, if $P < 0.05$, the H0 is rejected and consequently, H1 is accepted. If $P > 0.05$, the H0 is accepted and consequently, H1 is rejected.

Appendix XII: Results

Demographic gender differences:

Table 16: Gender differences in weight, height and hip circumference according to the unpaired t-test:

Category	t-value	P-value
Hip circumference▒	1130.5	**0.011**
Weight	7.269	**0.000**
Height	10.296	**0.000**

P > 0.05: no statistically significant difference between male and female
P < 0.05: there is a statistically significant difference between male and female
▒ Not normally distributed: U-value and P-value provided by the Mann-Whitney test was used instead of the t-value and P-value provided by the unpaired t-test.

Table 17: Gender differences in general performance for NMC tests 1 to 7 according to the Mann-Whitney U-test:

Outcome	U-value	P-value
GP Test 1	1525	**0.803**
GP Test 2	1520	**0.788**
GP Test 3	1458.5	**0.530**
GP Test 4	1489.5	**0.656**
GP Test 6	1503	**0.714**
GP Test 7	1559	**0.967**

P > 0.05: no statistically significant difference between male and female
P < 0.05: there is a statistically significant difference between male and female

Correlations:

The Kolmogorov-Smirnov test was used for normality of distribution. The Pearson and Spearman tests were used for correlation.

Table 18: Total weight, height and hip circumference in relation to general performance

	Total (n=112)						
Outcome	**Distribution**	**Weight**		**Height**		**Hip circ.**	
		r_s	**P**	**r_s**	**P**	**r_s**	**P**
GP Test 1	0.000	-0.058	0.541	0.01	0.92	-0.042	0.657
GP Test 2	0.000	0.088	0.354	0.135	0.157	0.097	0.31
GP Test 3	0.000	0.057	0.55	0.123	0.195	0.042	0.663
GP Test 4	0.007	0.068	0.478	0.106	0.267	0.012	0.899
GP Test 6	0.001	0.089	0.349	0.101	0.287	0.07	0.46
GP Test 7	0.000	-0.054	0.569	0.056	0.559	-0.058	0.545

P > 0.05: no correlation
P < 0.05: there is a correlation
Circ.: circumference; r_s: Spearman correlation coefficient; P: P-value; GP: General performance

Table 19: Female weight, height and hip circumference in relation to general performance

	Female (n=58)						
Outcome	**Distribution**	**Weight**		**Height**		**Hip circ.**	
		r_s	**P**	**r_s**	**P**	**r_s**	**P**
GP Test 1	0.0	-0.178	0.182	-0.16	0.229	-0.108	0.421
GP Test 2	0.003	0.113	0.399	0.059	0.659	0.019	0.889
GP Test 3	0.0	0.202	0.129	0.248	0.061	0.058	0.663
GP Test 4	0.061 ┼	0.258	0.05	0.2	0.132	0.119	0.374
GP Test 6	0.0	0.221	0.095	0.235	0.076	0.114	0.394
GP Test 7	0.0	0.038	0.778	0.064	0.631	0.036	0.786

P > 0.05: no correlation
P < 0.05: there is a correlation
Circ.: circumference; r_s: Spearman correlation coefficient; P: P-value; GP: General performance

┼ Normally distributed: Pearson correlation coefficient was used

Table 19: Male weight, height and hip circumference in relation to general performance

	Male (n=54)						
Outcome	**Distribution**	**Weight**		**Height**		**Hip circ.**	
		r_s	**P**	**r_s**	**P**	**r_s**	**P**
GP Test 1	0.0	-0.017	0.902	0.159	0.252	0.002	0.986
GP Test 2	0.012	0.028	0.84	0.272	0.047	0.148	0.287
GP Test 3	0.001	0.052	0.707	0.264	0.054	0.041	0.766
GP Test 4	0.178 ┼	-0.032	0.816	0.241	0.079	-0.076	0.587
GP Test 6	0.178 ┼	-0.131	0.343	-0.066	0.638	-0.102	0.462
GP Test 7	0.022	-0.115	0.409	0.109	0.433	-0.169	0.223

P > 0.05: no correlation
P < 0.05: there is a correlation
Circ.: circumference; r_s: Spearman correlation coefficient; P: P-value; GP: General performance

┼ Normally distributed: Pearson correlation coefficient was used

Deviations, maximum deviations and maximum ranges gender differences:

Most of the outcome variables of the NMC tests presented in the following tables 20, 21 and 22 were not normally distributed, therefore the Mann-Whitney U-test was used determining statistically significant gender difference. Exceptions are marked with a cross. For exceptions, the unpaired t-test was used.

Table 21: Gender differences in deviations, maximum deviations and range for NMC test 3 according to the Mann-Whitney U-test:

Outcome	U-value	P-value
F avg dev (°)	1566	**1**
B avg dev (°)	1269	**0.084**
F max dev (°)	1478.5	**0.61**
B max dev (°)	1496.5	**0.686**
F-B max range (°)	1530	**0.834**

Max: Maximum; F: Front; B: Back; avg dev: average deviation
P > 0.05: no statistically significant difference between male and female
P < 0.05: there is a statistically significant difference between male and female

Table 22: Gender differences in deviations, maximum deviations and range for NMC test 4 according to the Mann-Whitney U-test:

Outcome	U-value	P-value
L avg dev (°) ┼	-0.384	**0.702**
R avg dev (°) ┼	0.132	**0.895**
L max dev (°)	1422.5	**0.403**
R max dev (°)	1342.5	**0.193**
L-R max range (°)	1334.5	**0.178**

Max: Maximum; L: Left; R: Right; avg dev: average deviation
P > 0.05: no statistically significant difference between male and female
P < 0.05: there is a statistically significant difference between male and female
┼ Normally distributed: t-value and P-value provided by the unpaired t-test was used instead of the U-value and P-value provided by the Mann-Whitney test.

Speed outcome variable and gender differences:

The front-back and left-right speed in NMC tests 3 and 4 presented in table 23 and 24 were not normally distributed, therefore median and interquartile range values were retained and the Mann-Whitney test was used for the difference analysis.

Table 23: Speed for NMC tests 3 and 4 in number of back and forth trips from front to back or left to right

	Total (n=112)		Female (n=58)		Male (n=54)	
Outcome	Median	IQR	Median	IQR	Median	IQR
Test 3 L-R avg speed◊	6	4	6	5	6	3
Test 4 F-B avg speed◊	5	5	5	5	6	4

3: Dynamic left-right balance test; 4: Dynamic front-back balance test
IQR: Interquartile range; L: Left; R: Right; F: Front; B: Back; avg: average
◊ in number of back and forth trips from front to back or left to right

Table 24: Gender differences in speed for NMC tests 3 and 4 according to the Mann-Whitney U-test:

Outcome	U-value	P-value
Test 3 L-R avg speed◊	1437.5	**0.451**
Test 4 F-B avg speed◊	1428	**0.419**

3: Dynamic left-right balance test; 4: Dynamic front-back balance test
P > 0.05: no statistically significant difference between male and female
P < 0.05: there is a statistically significant difference between male and female
◊ in number of back and forth trips from front to back or left to right

Smoothness gender differences:

Table 25: Gender differences in smoothness for NMC tests 3 and 4 according to the Mann-Whitney U-test:

Outcome	U-value	P-value
Test 3 Smoothness	1400	**0.264**
Test 4 Smoothness	1389	**0.206**

3: Dynamic left-right balance test; 4: Dynamic front-back balance test
P > 0.05: no statistically significant difference between male and female
P < 0.05: there is a statistically significant difference between male and female

General performance differences according to smoothness:

Most of the general performances in NMC tests 3 (left-right dynamic balance test) and 4 (front-back dynamic balance test) presented in table 26 were not normally distributed, therefore median and interquartile range values were retained and the Mann-Whitney U test was used for difference analysis (table 27). Exceptions are marked with a cross. For exceptions, mean and standard deviation were used

Table 26: Smoothness of movement for NMC tests 3 and 4 in percentages

	T3 Smooth (n=58)		T3 Not Smooth (n=54)		T4 Smooth (n=37)		T4 Not Smooth (n=75)	
Outcome	Median	IQR	Median	IQR	Median	IQR	Median	IQR
GP Test 3 (%)	95	12	91	9.25	-	-	-	-
GP Test 4 (%)	-	-	-	-	94	10.5	86 ┼	9.05 ┼

3: Dynamic left-right balance test; 4: Dynamic front-back balance test
┼ Normally distributed: mean and standard deviations were used instead of median and interquartile range

Table 27: Smoothness difference in the general performance of tests 3 and 4 according to the Mann-Whitney U-test:

Outcome	U-value	P-value
GP Test 3	1071	**0.004**
GP Test 4	726,5	**0.000**

3: Dynamic left-right balance test; 4: Dynamic front-back balance test
P > 0.05: no statistically significant difference between smooth and not smooth
P < 0.05: there is a statistically significant difference between smooth and not smooth

Appendix XIII: Confidentiality statement

Fontys Paramedische Hogeschool

B8. Confidentiality statement

Name: Mc ALEER Sinéad Student No*: 2200582

Title:

Gender specific outcomes of the Neuromuscular Control tests with the Sensamove® therapy cushion.

Content (description):

What are possible differences in the outcomes of the Sensamove® therapy cushion NMC tests between 18 to 30 years old healthy men compared to 18 to 30 years old healthy women?

1. By signing this Statement, the Fontys Paramedic University of Applied Sciences in Eindhoven commits itself to keep any information concerning provided data and results obtained on the basis of research of which is taken cognizance as part of the above practical research project and of which it is known or can be reasonably understood that said information is to be considered secret or confidential, in the strictest confidence.
2. This confidentiality requirement also applies to the employees of the Fontys Paramedic University of Applied Sciences, as well as to others who by virtue of their function have access to or have taken cognizance of the aforesaid information in any way.
3. The above notwithstanding, the student will be able to perform the practical research project in accordance with the statutory rules and regulations.

Student:

Name: Mc ALEER Sinéad

(signature) Date: 14/12/2015

Supervisor:

Name: Annelies Simons

(signature) Date: 15/12/2015

Coordinator: for receipt

Name: Steven Oudelaar

(signature) Date: 14-12-2015

Appendix XIV: Conveyance of rights Agreement

Fontys Paramedische Hogeschool

B9. Conveyance of Rights Agreement

AGREEMENT

Pertaining to the conveyance of rights and the obligation to convey/return data, software and other means

The undersigned:

1. Mr/Ms Sinéad Nora Mc Aleer
   [full name as stated in passport], residing at 5612 HX Eindhoven
   [postal code, place of residence] at the Bendstraat 16
   [street and house number], hereinafter to be called "**Student**"

and

2. Fontys Institute trading under the name Fontys University of Applied Sciences, Rachelsmolen 1, 5612 MA Eindhoven, hereinafter to be called "**Fontys**"

CONSIDERATION

A. Student is studying at the Fontys Paramedic University of Applied Sciences in Eindhoven and is performing or will perform (various) activities as part of his/her studies, whether or not together with third parties and/or commissioned by third parties, as part of research supervised by the lectureship of Fontys Paramedic University of Applied Sciences. The aforesaid activities will hereinafter be called "**Lectureship Study Activities**". At the time of the signing of this Statement, the Lectureship of Fontys Paramedic University of Applied Sciences supervises in any case the studies listed in Appendix 1, but this list is not an exhaustive one and may change in the future.

B. It is of essential importance to Fontys Paramedic University of Applied Sciences that (the results of) the Lectureship Study Activities can be further developed and applied without any restriction by Fontys Paramedic University of Applied Sciences and/or used for the education of other students. Fontys wishes in any event – but not exclusively – (i) to be able to share with and/or convey to third parties (the results of) the Lectureship Study Activities, (ii) to publish these under its own name, where the Student may be named as co-author providing that this is reasonable under the circumstances, (iii) to be able to use these as a basis for new research projects.

C. In case intellectual ownership rights and/or related claims on the part of Student will be/are attached to (the results of) the Lectureship Study Activities, parties wish – taking into account that which was mentioned under (B) – Fontys Paramedic University of Applied Sciences to be the only claimant with regard to said rights and claims. The Student therefore wishes to convey all his/her current and future intellectual property rights as well as related claims concerning (results of) the Lectureship Study Activities to Fontys, subject to conditions to be specified hereafter;

D. Student furthermore wishes to enter into the obligation – again taking into account that which was mentioned under (B) – to convey all data collected by him/her as part of the (results of) the Lectureship Study Activities to Fontys and not to retain any copies thereof, and also to return all data, software and/or other means previously provided by Fontys as part of (the results of) the Lectureship Study Activities, such as measuring and testing equipment, to Fontys without retaining copies thereof, all the above being subject to conditions to be specified hereafter.

AGREE THE FOLLOWING

1. Conveyance of intellectual property rights

1.1 Student herewith conveys to the Fontys Paramedic University of Applied Sciences all his/her current and future intellectual property rights and related claims concerning (the results of) the Lectureship Study Activities, for the full term of these rights.

1.2 Intellectual property rights and/or related claims are understood to refer to, in any case – but not limited to – copyright, data bank law, patent law, trademark law, trade name law, designs and model rights, plant breeder's rights, the protection of know-how and protection against unfair competition.

1.3 The conveyance described under 1.1 shall be without restriction. As such, the aforesaid conveyance shall include all competences related to the conveyed rights and claims, and said conveyance shall apply to all countries worldwide.

1.4 Insofar as any national law requires any further cooperation on the part of Student for the conveyance mentioned under 1.1, Student will immediately and without reservation lend such cooperation at first request by Fontys Paramedic University of Applied Sciences

1.5 Fontys accepts the conveyance described under 1.1.

2. Waiver of personal rights

2.1 Insofar as permitted under article 25 'Copyright' and any other national laws that may apply, Student waives his/her personal rights, including – but not limited to – the right to mention Student's name and the right to oppose any changes to (the results of) the Lectureship Study Activities. If and insofar as Student can claim personality rights pursuant to any national laws notwithstanding the above, Student will not appeal to said personality rights on unreasonable grounds.

2.2 In deviation from that which was stipulated under 2.1, the Fontys Paramedic University of Applied Sciences may decide to mention the name of Student if this is reasonable in view of the extent of his/her contribution and activities.

3. *Compensation*

Student agrees that he/she will receive no compensation for the conveyance and waiver of rights as described in this Statement.

4. *Guarantee concerning intellectual property rights*

Student declares that he/she is entitled to the aforesaid conveyance and waiver, and declares that he/she has not granted or will grant in future, license(s) for the use of (the results of) the Lectureship Study Activities in any way to any third party/parties. Student indemnifies Fontys from any claims by third parties within this context.

5. *Obligation to convey/return data, software and other means*

5.1 At such a time as Student is no longer performing any Lectureship Study Activities and/or is no longer a student at Fontys, Student is obliged to convey to Fontys all data, in the widest sense of the word, collected by him/her as part of (results of) the Lectureship Study Activities, including – but not limited to – studies and research results, interim notes, documents, images, drawings, models, prototypes, specifications, production methods, process descriptions and technique descriptions.

5.2 Student guarantees not to have kept any copies in any way or form of the data meant under 5.1.

5.3 Student is obliged to return to Fontys all data, software and other means provided to him/her by Fontys as part of the Lectureship Study Activities, and guarantees not to have kept copies in any way or in any form, of the provided software and/or other means.

5.4 Student agrees that if he acts and/or proves to have acted contrary to the obligations mentioned under 5.1 up to and including 5.3, (a) he/she shall be liable for all and any damages incurred or to be incurred by Fontys, and (b) that this will qualify as fraud and that Fontys can apply the appropriate sanctions hereto. The sanctions to be applied by Fontys may consist of, among other things, the denying of study credits, the temporary exclusion of the Undersigned from participation in examinations, but also the definitive removal of the registration of the Undersigned as a student at Fontys.

Fontys Personeelliche Hogeschool

6. *Waiver*

Student waives the right to terminate this Agreement.

7. *Further stipulations*

7.1 Insofar as this Agreement deviates from the Student Statute, this Agreement shall prevail.

7.2 This Agreement is subject to Dutch law. All disputes resulting from this statement will be brought before the competent judge in Amsterdam.

Student:	**Fontys Institute trading under the name Fontys Hogescholen Supervisor:**
Name: Sinéad Nora Mc Aleer	Name: Amelies Simons
(signature)	(signature)
Date: 15/12/15	Date: 15/12/15
Place: Eindhoven	Place: Eindhoven

I, Ms. M.H. de Waard, sworn translator for the English language registered at the Court in Groningen, the Netherlands, and registered in the Dutch Register of Sworn Translators and Interpreters (Rbtv) under nr. 2202, herewith certify the above to be a true and faithful translation of the attached Dutch document into the English language.

Groningen, 23 May 2012,

[M.H. de Waard]