The Only Way Is Up!

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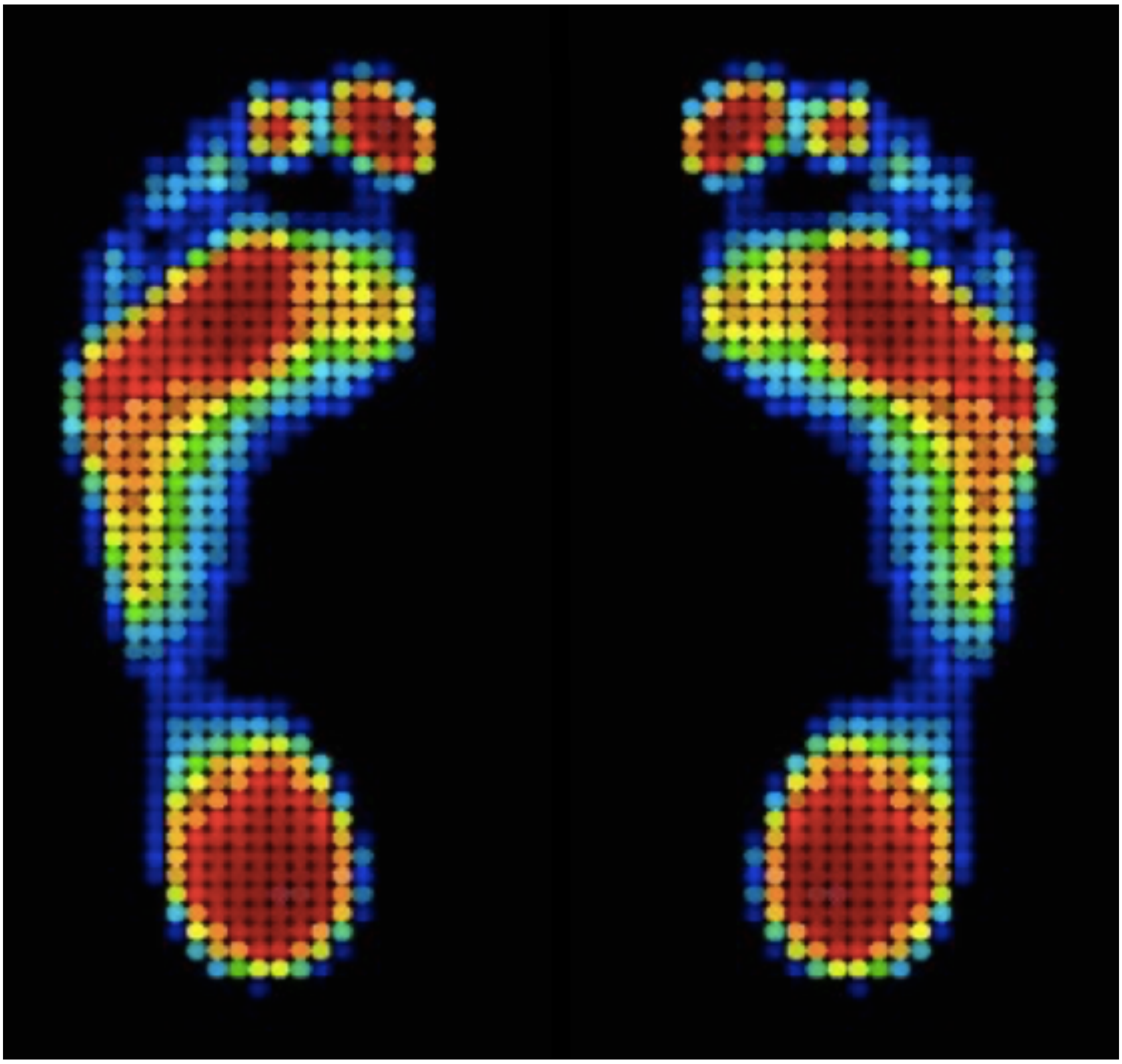

Human Kinetic Technology | The Hague University of Applied Sciences
B. W. M. van Hout
W. F. Sinnema
Innsbruck
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Human Kinetic Technology | The Hague University of Applied Sciences (THUAS)
Technology Centre of Ski and Alpine Sports (TCSAS)

Authors	B. W. M. van Hout W. F. Sinnema
Primary supervisor THUAS Secondary Supervisor THUAS	H. N. Meulman A. A. Witkam
Supervisors TCSAS	J. van Putten C. Hasler

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Thesis Human Kinetic Technology

Preface

We wrote this bachelor thesis in our role as fourth-year Human Kinetic Technology students.

Testing hiking shoes independently is what the founder of project OutFeet inspired us to develop this pre-study.
This thesis is intended for the founders of project OutFeet. This study has led to an extensive data collection which will assist in interpreting data for further research.

This thesis has been co-founded with the help of various persons. We especially want to thank the project supervisors, Christoph Hasler and Joost van Putten, for their contribution. Due to their professional knowledge and critical eye, this research has come to a functional final design. We also want to thank the Lab Manager, Armin Niederkofler. He taught us how to use various measurement equipment.
In addition, we would like to thank the graduation counsellor, Hubert Meulman. Due to his background as a teacher and his professional knowledge, he has helped us to complete this project in a good manner.
Last but not least, we would like to thank the subjects and colleagues of the Technology Centre of Ski and Alpine Sports. They made a significant contribution to the results of this project.

Innsbruck, June 2017

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Abstract

Wellbeing, comfort and safety in outdoor shoes have always been based on parameters that vary from person to person (male, female, weight, build, etc.). The aim of the project OutFeet was to go beyond this subjective approach by taking a merely qualitative analysis to a higher scientific level.

The aim of this study was to discover a difference in the pattern of the parameters that work on the foot during uphill, downhill and level walking. Medilogic insoles were used. This measurement system is able to measure the pressure and the pressure distribution whilst wearing the shoe.

This research was divided into two parts. In order to determine whether the Medilogic insoles are capable of measuring the exact pressure respectively to the pressure distribution, a validation study was performed first. The pressure measurements obtained by the Medilogic insoles were compared to the Kistler force plate. The Kistler force plate measures forces in X, Y and Z-axes and is considered as golden standard.
This validation study gave answer to the question: Are the pressure values given from the Medilogic insoles consistent with the golden standard force values measured by the Kistler force plate?
The calculated correlations between the two measurement equipment provided information about the accuracy of the Medilogic insoles.

For the measurements ten healthy subjects (five male, five female) with an average age and weight of 28.7 years (range of 22-40 years), 71.9 kg (56-84 kg range) and a shoe size of EU 39/40 (n = 5) and EU 43/44 (n = 5) participated.

To answer this question, three measurements were taken:

- A static measurement with known weights. This was done to calculate the amplification factor. This is the gradient of the regression line.
- A static measurement with subjects. They were told to stand alternating on their heels, toes, leaning on the medial and lateral sides of their feet and central. This was done to see if there were any differences in correlation when the insole was divided into different areas.
- A dynamic measurement in which the subject walked back and forth. This was done to see if the insoles perform in the same way while walking as during static measurements.

The conclusion of the validation study was that the Medilogic insoles are accurate for static weights, the founded correlation was 0.99. As soon as measurements were performed with persons it became clear that the insoles were not accurate for determining the absolute amount of the force. The correlation was below 0.80. This could be due to curling or shifting of the insole underneath the foot, shape differences of the foot or the sensor registration. It could have also been that the subjects did not perform the asked positions well. However, the mutual pressure distributions in the sole could be measured. Therefore, the Medilogic insoles were used for the final research.

The main question for the final research was drawn up: Which of the drafted parameters that work on the foot are significantly different at an inclination angle of +12%, 0% and -12%, in comparison to each other.

The drafted parameters are:

1. Total time step time.
2. Time difference between the beginning and the maximum force of the posterior phase.
3. Time difference between the maximum force of the posterior phase and the intersection.
4. Time difference between the intersection and maximum force of the anterior phase.
5. Ratio between the heights of the peaks.
6. Ratio between the width of the anterior- and posterior phase.

Before this main question could be answered a ramp had to be designed following the prerequisites and demands. The prerequisites came from researchers from the OutFeet project and the limitations of the Technology Centre of Ski and Alpine Sports. The demands follow from the analysis. After constructing the ramp, measurements were done to provide an answer to whether there were significant differences between uphill, downhill and level.

Based on the prerequisites and demands a single concept was created and developed into a final design.

The main question of the final research was answered with three measurements:

- A dynamic measurement in which the subject walks back and forth with 0% inclination. This is done to obtain a reference value.
- The other two dynamic measurements are done on top of a self-designed ramp. The subject walks up (+12% inclination) and down (-12% inclination) the ramp.

In some of the parameters a significant difference between the conditions was found. All the conclusions relate only to an inclination of +12%(uphill), 0%(level) and -12%(downhill).

Reasons for the different outcomes could be that the inclination of the ramp was only +12% or -12%. It could be that the steepness of the ramp was too little to give a change in the walking patterns of the subjects. Another reason could be the small group of subjects. Therefore, outliers could have influenced the results.
The subjects walked with their preferred walking speed. The way of processing data may affect the data. Whilst using MATLAB, the reference points in the graphs, except for the maximum force of the posterior phase and the maximum force of the anterior phase, are manually applied. This is not a secure way to get the correct values. Sensors register pressure only when pressure works on the middle of the sensor. For this reason, it could be that the HC was registered later than the initial contact. It could also appear that the actual TO-phase should have taken longer but the sensors did not register anything any longer.

The main question of this research was: Which of the drafted parameters that work on the foot are significantly different at an inclination angle of +12%, 0% and -12% in comparison to each other.
For all the parameter has been found at least one significant difference with in the three different conditions except from parameter 5.

Conditions of the parameters that were found to be significantly different were:
Parameter 1: The difference between uphill & downhill walking was found to be significant (0.040).
Parameter 2: The difference between uphill & downhill and uphill & level walking were found to be significant (<0.001).
Parameter 3: The difference between uphill & downhill and uphill & level walking were found to be significant (0.005).
Parameter 4: The difference between uphill & downhill (0.001) and downhill & level walking (0.002) were found to be significant.
Parameter 6: The difference between uphill & downhill and uphill & level walking were found to be significant (0.005).

1. Introduction

Wellbeing, comfort and safety in outdoor shoes have always been based on parameters that vary from person to person (male, female, weight, build, etc.). The aim of the project OutFeet is to go beyond this subjective approach by taking a merely qualitative analysis to a higher scientific level. Tradespeople and consumers (excursionists, sportspeople, etc.) will be able to benefit from guaranteed and reliable criteria. For companies, this will provide more know-how when designing and producing outdoor footwear, while consumers will be more knowledgeable about product features. All this becomes particularly important in the program area (Interreg Italia - Österreich), where outdoor shoes are used in many activities, not just in sports (such as mountain rescue work) and where there are many companies in the sector. Comfortable footwear makes for safe footwear: this reduces the consequences of any accidents and therefore social costs. The partners will be involved in – according to their specific know-how – collecting field data, prototyping sensorized devices, and comparing real and scientific data, thus developing a standard method. (European Union, 2016)

Researchers of the project OutFeet want to know how a hike looks like at every step. They want to know if it is possible to see differences between uphill, downhill and level walking. They want to achieve this by measuring the pressure and pressure distribution. It is important to know how these parameters behave. This way it is possible to see how a shoe acts in different circumstances. To see under what inclination angle a person hikes up- or downhill a GPS-system is often used. With a GPS-system an overview of the inclination of the total hike can be given, but a detailed data analysis of every step is not possible (El-Rabbany, 2002). Therefore a different measuring system should be used.

A measurement device to measure the pressure and the pressure distribution is the Medilogic pressure insole. For a static measurement, researchers found an average correlation of 0.998 (Koch, Lunde, Ernst, Knardahl, & Veiersted, 2016) and 0,866 (Price, Parker, & Nester, 2016). The Medilogic insoles can measure the pressure and the pressure distribution on the soles during the time.

The aim of this study is to discover a change in the pattern from the parameters that work on the foot during uphill, downhill and level walking.
Research about traction coefficients, foot-floor angles during level, downhill, uphill, and cross-slope walking was done. These parameters were analysed on a self-designed ramp (Wannop, Worobets, Ruiz, & Darren, 2014). Other researchers wrote an article about the plantar loading changes during five gradient conditions on a treadmill using the Pedar in-shoe pressure measurement system (Grampp, Willson, & Kernozek, 2000). In this research, the two studies discussed above are combined.

It is already known that the Medilogic insoles can measure the mutual pressure distribution under the foot. This means, the Medilogic insoles can measure value differences between the sensors of the insole. In order to determine whether the Medilogic insoles are capable of measuring the exact pressure respectively to the pressure distribution, a validation study is performed first. This validation study gives answer to the question: Are the pressure values given from the Medilogic insoles consistent with the golden standard force values measured by the Kistler force plate?
The calculated correlations between the two measurement equipment gives information about the accuracy of the Medilogic insoles. If the correlations are above .800, the obtained exact values can also be used in the next research, otherwise the insoles are only used to find differences in the pressure distribution.
The final study is conducted when the validation study is completed.

The main question for the final research was drawn up: Which of the drafted parameters that work on the foot are significantly different at an inclination angle of +12%, 0% and -12%, in comparison to each other.

The drafted parameters are:

- Total time step time.
  The total step time was evaluated because it is presumed that there is a difference with walking uphill, downhill or level walking.
- Time difference between the beginning and the maximum force of the posterior phase.
  This parameter gives an indication of the time period of heel contact (HC) until the moment of total load on the posterior part of the foot.
- Time difference between the maximum force of the posterior phase and the intersection.
  This parameter gives an indication of the time period to roll over until midstance.
- Time difference between the intersection and maximum force of the anterior phase.
  This parameter gives an indication of the time period to roll over from midstance until toe off.
- Ratio between the heights of the peaks.
  The ratio is the proportion in which the one is bigger in comparison to the other. A ratio of one means the value of the parameters are the same.
- Ratio between the width of the anterior- and posterior phase.
  This parameter indicates if the time the subject stays on one part longer than the other.

Before this main question can be answered a ramp has to be designed following the prerequisites and demands. The prerequisites come from researchers from the OutFeet project and the limitations of the Technology Centre of Ski and Alpine Sports (TCSAS). The demands follow from the analysis. After constructing the ramp, measurements will be done to give an answer to whether there were significant differences between uphill, downhill and level walking.

This study is divided into two parts. The first part of the paper consists of chapters 2 to 6. The second part will start at chapter 7. Chapter 2 of this report discusses the method of validation study. This includes: general information, requirements, explanation of measurements and vocal instructions. Chapter 3 deals with the processing of the data of the three measurements. Chapter 4 shows the results of the validation study. The discussion points of the validation study are discussed in chapter 5. Chapter 6 deals with the conclusion of the validation study.
The design report starts at chapter 7, in this chapter the analysis phase is discussed. The prerequisites are discussed in chapter 8. Chapter 9 shows the design phase. The method of the final research is discussed in chapter 10. How the data is processed is argued in chapter 11. The results are showed in chapter 12. Chapters 13 and 14 consist of the discussion and the conclusion. Lastly, there is a reference list and the appendices.

2. Method I

Three different measurements were done. The protocols of the three measurements will be discussed in this chapter. For every measurement, a correlation between the measured force of the Medilogic insoles and the measured force of the Kistler force plate will be calculated.

2.1. Protocols

2.1.1. General information

In this chapter 2.1.1., general information will be discussed. This will be used for every measurement.

2.1.1.1. Subjects

For this study, ten healthy subjects (five male, five female) with an average age and weight of 28.7 years (range of 22-40 years), 71.9 kg (56-84 kg range) and a shoe size of EU 39/40 (n = 5) and EU 43/44 (n = 5) participated. The subjects vary in weight to create a clear spread in the data. The subjects were previously informed about the purpose of this study by an information letter, see appendix A1. Appendix A2 gives an overview about the person-related information.

2.1.1.2. Footwear

In order to have as few variables as possible, it was chosen to use the same shoes for every subject during the test. The used shoes are Adidas indoor shoes, See Figure 2.1. The choice of this shoe is based on the fact that the indoor shoes were available in several sizes at the Technology Centre of Ski and Alpine Sports (TCSAS).

Figure 2.1: Adidas indoor shoes

2.1.1.3. Medilogic pressure sensors

There were several shoe sizes of the Medilogic insoles available at the TCSAS. For this study, EU 39/40 and EU 43/44 sizes are used. The used sizes are the most common shoe sizes for women and men. The larger the size of the sole, the more sensors the Medilogic insole contains. Two different sizes are measured to exclude differences between sizes. The Medilogic insoles measure the pressure [N/cm^2] of foot against time [s]. The frequency at which the Medilogic insoles measured was set on 30 Hz. In figure 2.2 the Medilogic insoles, the transmitter and receiver are shown.

Figure 2.2: Medilogic pressure insoles with transmitter and receiver.

2.1.1.4. Kistler force plate

The Kistler force plate measures in three axes namely X, Y and Z. Figure 2.3 shows the Kistler force plate with the orientation of the axes, X (red), Y (green) and Z (black). For this study, only the Z-axis was used. The Medilogic measures in this direction as well. This makes the signals comparable. The frequency of the platform was set on the same frequency as the Medilogic insoles.

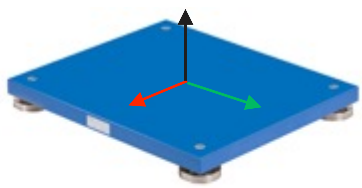


Figure 2.3: Kistler force plate.

2.1.2. Protocol static measurement with weights

This protocol is written not only to determine the correlation between the Medilogic insoles and the Kistler force plate but also to calculate the amplification factor. The amplification factor is the gradient of the regression line. This can predict the default measurement error. This factor is needed for further measurements with the Medilogic insoles. In this way, the difference between the Medilogic insoles and the Kistler force plate can be levelled out.

2.1.2.1. *Requirements*

- Medilogic insoles (size EU 39/40 & EU 43/44).
- Adidas indoor shoes (size 39, 40, 43 & 44).
- Kistler force plate.
- Weights (1*5 kg, 1*10 kg, 3*20 kg).

2.1.2.2. *Measurement*

Two static measurements were done with the Medilogic insoles. The first measurement contains the left Medilogic insole. This sole was placed on the Kistler. Five Kg is placed on the sole. Both the Medilogic insoles and the Kistler force plate measure for twenty seconds.
After twenty seconds the Medilogic insoles and the Kistler force plate were charged with an extra five Kg. This process repeated itself up to sixty Kg. Five Kg increments have been chosen because the weight differences between the subjects were small. The distinction between weights with pressure is therefore better to prove. There were no more weights available than up to sixty Kg. When a new weight was added, a new measurement was performed. The same measurements were performed for the right Medilogic insole. See Figure 2.4.

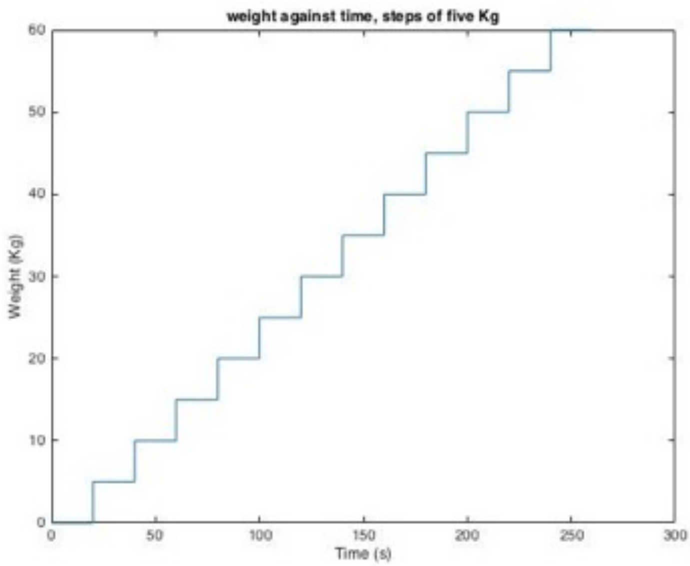


Figure 2.4: Example of how the load on the Medilogic insoles and Kistler force plate was set against time. Every 20 seconds, the weight increases with five Kg.

2.1.3. Protocol static measurements with subjects

This protocol is written to determine if there is any difference in correlation when the insole was divided into different areas.

2.1.3.1. Requirements

- Medilogic insoles (size EU 39/40 & EU 43/44).
- Adidas indoor shoes (size EU 39, 40, 43 & 44).
- Kistler force plate.
- Chair.

2.1.3.2. Measurement

2.1.3.2.1. The measurement

The Kistler force plate gives the total amount of force, no distinctions are made between the left and right foot. In this validation study the left and right foot were compared, because of this the measurements were performed twice. The first measurement was done with the left foot on the force plate, the second measurement was done with the right foot on the force plate. See Figure 2.5 and 2.6.

Figure 2.5: Right foot on the force plate

Figure 2.6: left foot on the force plate

During the measurement on the force plate, the subject wore the Medilogic insole sensors. The subject was told to give a kick on the force plate with the foot next to the force plate. The kick was performed to have a synchronisation point in the data of the Medilogic insoles and the Kistler force plate.
After the kick on the Kistler force plate, the subject performed five different positions. The positions had to be practised before the measurement took place. This way the subject becomes more comfortable and is more likely to perform the same positions.
The five positions were:

- Leaning on the front of the soles, the subject stands on the toes.
- Leaning on the back of the soles, the subject stands on the heels.
- Leaning on the medial side of the foot.
- Leaning on the lateral side of the foot.
- Neutral position, the subject stands with their feet flat on the force plate.

The subject was holding a chair for support while standing in the different positions. Because the subject was holding the chair, he/she could maintain a better balance. If the subject was not holding onto the chair the signal was not stable enough to process because the signal fluctuated too much. Holding onto the chair has an influence on the stability of the subject and on the signal of both the Kistler force plate and the Medilogic insoles.

The chair is located next to the platform. After performing a position for ten seconds, the subject stepped off the force plate. For every position, a new measurement was done. The positions were performed in the same order for all the subjects.

2.1.3.2.2. Vocal Instructions

'You will be standing next to the force plate.' 'On our sign, you are giving a kick on the force plate.' 'After the kick, you are going to stand in position we say.' 'You hold this position for ten seconds.' 'After the ten seconds, you step off of the force plate.' 'The different positions are: Standing on your toes, standing on your heels, leaning on the inside, leaning on the outside and last just normal.' 'You have to hold the chair during the postures because you have to stand as still as possible.' 'I will show you how to do it.' 'You have to practice now.' 'We do the same positions with the other foot on the force plate.'

2.1.4. Protocol dynamic measurement with subjects

This protocol is performed to see if the insoles behave the same as at static measurements while walking.

2.1.4.1. Requirements

- Medilogic insoles (size EU 39/40 & EU 43/44).
- Adidas indoor shoes (size EU 39, 40, 43 & 44).
- Kistler force plate.

2.1.4.2. Measurement

2.1.4.2.1. The measurement

Two measurements were made. For the first measurement, the subject had to walk back and forth across the Kistler force plate. The left foot had to make a step on the force plate. For the second measurement, the same principle had to be performed but this time the right foot had to step on the force plate. The subject was wearing the Medilogic insoles during the walk.

The subject had to make five normal steps plus one step where the subject closes his/her step. Two steps had to be made before the force plate, one step is performed on the force plate and two steps were made at the end. To finish the walking trail, the subject had to close their legs.
The way of walking was performed in this manner to guarantee that the subject had a comfortable speed and did not lose velocity after or during the step on the force plate. After closing the step, the subject had to stand in this position for ± (min four/max six) five seconds. After ± five seconds, the subject turned 180° with small steps. The subject had to stay in this position again for ± five more seconds. This way it was clear to see in the data when the person is changing the direction. See Figure 2.8.

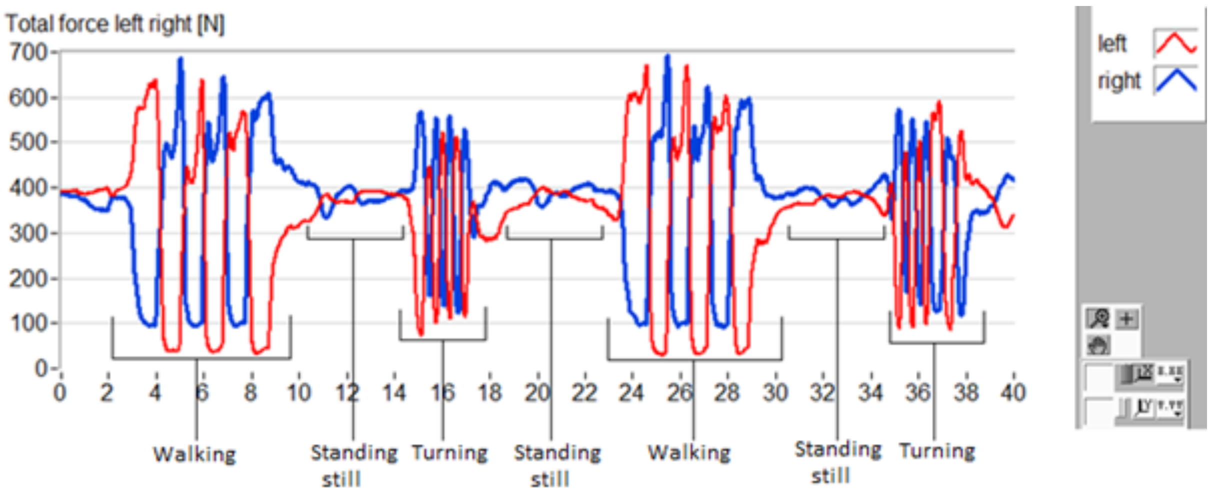


Figure 2.8: Walking signal of the Medilogic insoles created by LabVIEW. Force [N] against time [s]. Blue line represent the right foot, the red line represent the left foot.

2.1.4.2.2. Vocal Instructions

'In total, we will do two measurements, I will explain the first one.' 'You are starting to walk with your left foot, with the intention to step with you left foot on the force plate ones.' 'Before your foot touches the force plate you walk two steps and after the force plate you walk two steps more.' 'At the end, you close your step with the other foot.' 'After the steps, you stand still for five seconds.' 'After that, turn around with small steps and stand still again for 5 more seconds.' 'After the five seconds, you start walking back again with your left foot first.' 'We do this five times.' 'I will show you how to do it.' 'You have to practice it.'

'For the second measurement, we will do the same.' 'The only difference is that you have to start your right foot for five times.' 'You have to practice again.'

3. Data processing

This chapter discusses the way the data is processed. First the general information will be discussed. This refers to all the measurements. Then the data processing is discussed which is specifically applicable to the different protocols.

3.1. General information

3.1.1. Data processing with LabVIEW™ 2015

The data from the Medilogic insoles was exported as a CSV file. This file was loaded into LabVIEW. LabVIEW was used as an interface for hardware for testing, measuring and controlling. Data can also be analysed and systems distributed using visual programming.
The interface used in this study calculated the average force [N] versus time [s]. The data from LabVIEW was exported to an Excel file. After editing the Medilogic insoles data to a force signal, the data was comparable to the data of the force plate.

3.1.2. Data processing with IBM© SPSS© statistics 24

For every measurement an average value was calculated for the left and the right Medilogic insole. For the statistic measurement with weights an average was calculated for every weight step. In chapter 3.2.1. it is discussed how this is done. For the statistic measurement with weights, an average value per person per position was calculated. Chapter 3.3.1. discusses how this is done. For the dynamic measurement, an average value of the toe off phase(TO) was calculated. Chapter 3.4.1. discussed how this is done. The average values were used to compare the measuring instruments. A correlation was calculated between the value of the Medilogic insoles and the value of the Kistler force plate.

A scatter plot was made to clearly understand the relationship between the two measuring instruments. A scatter plot is a graphical representation of the relationship between two variables. In the scatter plot, the Kistler data was plotted on the X-axis and the data of the Medilogic insole on the Y-axis.

To see if the data was normally distributed, the Kolmogorov-Smirnov test was performed in SPSS. When the significance was > 0.05, the Pearson test was performed to calculate the correlation. When the significance was < 0.05 the Spearman test was performed to calculate the correlation. (Grampp, Willson, & Kernozek, 2000)

3.2. Static measurement with weights

3.2.1. Data processing with Microsoft Excel

The Medilogic insoles data was converted into a force signal [N] vs. time [s] using the LabVIEW program. After the Medilogic insoles data was converted, an average was calculated of the last five seconds of the signal of every step. The average of the last five seconds of Kistler force plate data was also calculated. This is done for every step.

A correlation was calculated of all the average values of the Medilogic insoles and the Kistler force plate. Two correlations were calculated for every Medilogic insole size (EU39/40 L, EU39/40 R, EU43/44 L, EU43/44 R).

3.3. Static measurement with subjects

3.3.1. Data processing with MATLAB®, MathWorks 2015b

For each position there was an excel file, for the left and right foot, for both the Kistler force plate and the Medilogic insole for every subject.
The Excel files from the left and right foot of the Kistler force plate were loaded into MATLAB. MATLAB searched for highest peak value, the point where the subject gave a kick on the force plate. It was checked if the kick was the highest value in the data. If this was not the case, this was manually entered. Three seconds after the kick MATLAB calculated an average of one and a half seconds of the signal. After the kick on the force plate, the subject needed time to stabilize and to get in the correct position. Getting in the right position and stabilizing takes ± three seconds. See Figure 3.1.

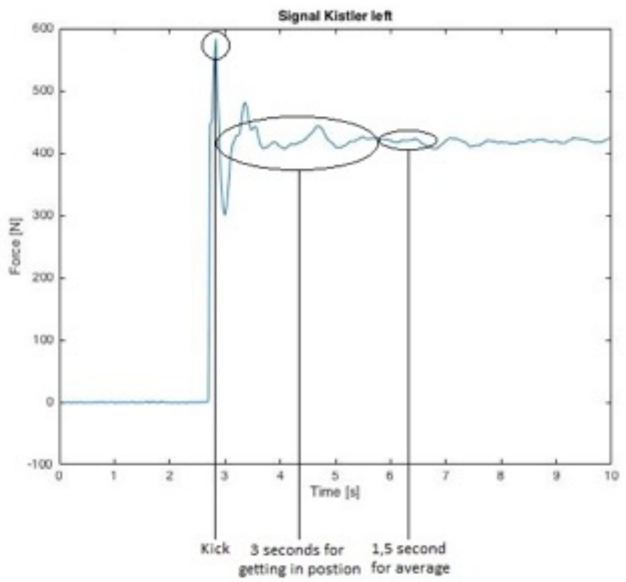


Figure 3.1: Data signal of the Kistler. The peak represents the kick on the force plate. The next 3 seconds, the subject is getting in the right position and stabilizes. Right after the 3 seconds, an average of 1,5 s is calculated.

The same was done for the Medilogic insole data left and right.

To summarise, for every subject in each position from each sole (left, right, 39/40 & 43/44) a correlation was calculated. This was done as described in chapter 3.2.1. The MATLAB code can be found in appendix A2

3.4. Dynamic measurement with subjects

3.4.1. Data processing with Excel

For the Medilogic insoles, there is one data signal with data of the five times walking back and forth walking. In LabVIEW, only the leg which had contact with the Kistler force plate was analysed. When the subject walks to the other side of the track, the subject made three steps with left and three steps with right. The middle step of the three steps from the Medilogic insole signal had be compared to the step on the force plate. A small range around the peak of the middle step data is selected and exported to Excel. Excel searches for the peak of the toe off phase (TO). See Figure 3.2. This peak is easy to recognise in the signal.
For each subject, a peak is detected in five separate files for left and in five separate files for right.

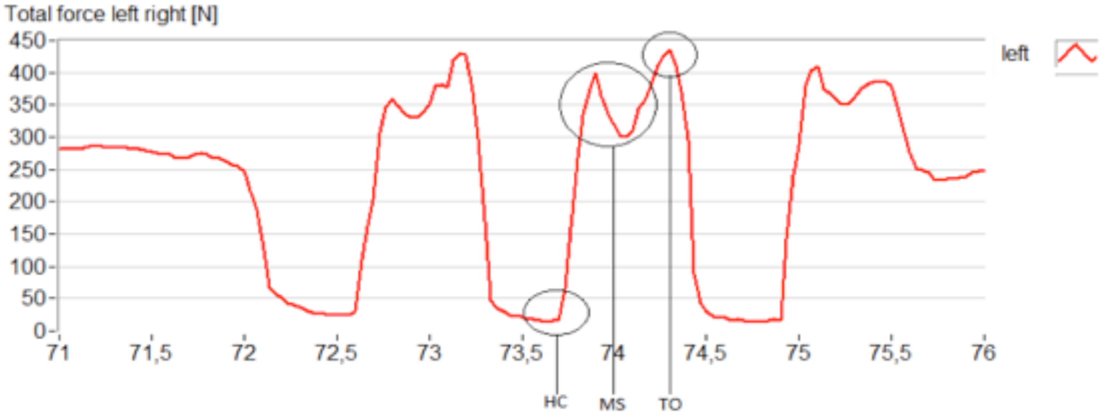


Figure 3.2: overview of walking signal from the Medilogic, the second step will be analysed. HC: Heel contact, MS: Midstance, TO: Toe off.

For the Kistler force plate data, there was a separate Excel file for each step because the Kistler force plate could measure no longer than 20 seconds. In Excel the peak of the TO was looked for as well because of the easy recognition of the peak. It was also better to look at the TO instead of the heel contact (HC) because of the vibrations during the initial contact with the floor. For each subject the peak value was detected in five separate files for left and in five separate files for right. See Figure 3.3 for an impression of the Kistler force plate signal.
For each shoe size, left and right, a correlation was calculated. This was done as described in chapter 3.2.1.

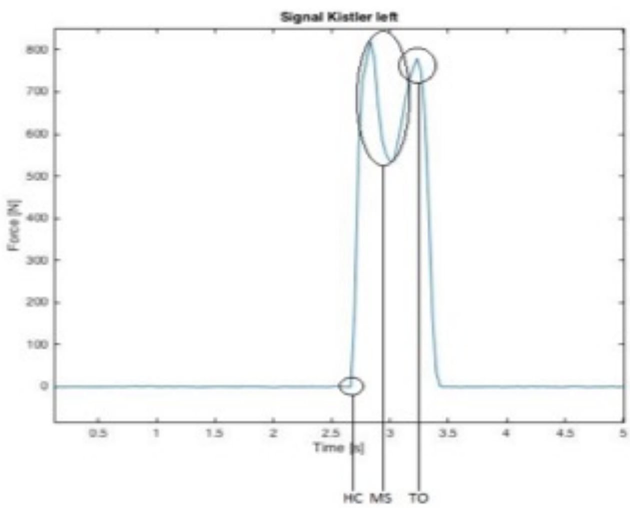


Figure 3.3: Overview of walking signal of the Kistler force plate. HC: Heel contact, MS: Midstance, TO: Toe off.

4. Results I

In the previous chapters the three different measurements were described. This chapter will discuss the results. For every measurement is a separate table.

The table 4.1 below shows the results of static measurement with weights. Two different shoe sizes have been measured, and also the left and right insole. This results in a total of four correlations.
All the correlations are above 0.9.

Table 4.1: Static measurement with weights. A correlation is found with weight steps of five Kg.

Static measurement with weights				
	Correlation left	Correlation right	Amplification factor left	Amplification factor right
39/40	0.993	0.998	0.40	0.48
43/44	0.992	0.995	0.47	0.48

The table 4.2 below shows the results of static measurement with subjects. For all of the five positions a correlation is calculated. This is done for left and right insole of size 39/40 and 43/44.
The correlations from table 4.2 are above 0.8 for standing on the toes and standing central. For the rest of the categories the correlations have a big variety between them. Overall, there is not much difference between shoe size 39 and size 43.

Table 4.2: Static measurement with subjects in five different positions. 39: insole 39/40 43: insole 43/44

Static measurement with subjects				
	Correlation left 39	Correlation right 39	Correlation left 43	Correlation right 43
Toes	0.866	0.900	0.814	0.943
Heels	0.429	0.769	0.850	0.474
Medial	0.613	0.649	0.568	0.701
Lateral	0.532	0.709	0.931	0.588
Central	0.954	0.811	0.917	0.905

The table 4.3 below shows the results of dynamic measurement with subjects. Two different shoe sizes were measured and also to the left and right insole. This results in a total of four correlations. The correlations from table 4.3 have a big variety between them.

Table 4.3: Dynamic measurement, subjects walks five times across the Kistler force plate with the Medilogic insoles in the shoes. 39: insole 39/40 43: insole 43/44

Dynamic measurement with subjects			
Correlation left 39	Correlation right 39	Correlation left 43	Correlation right 43
0.75	0.632	0.423	0.623

5. Discussion I

The values of the Medilogic insoles are not consistent with the golden standard force values measured by the Kistler force plate. To find different patterns of the pressure distribution on the foot the Medilogic soles are suitable. This means that the sensors can measure the differences between one another. Medilogic GmbH calibrates the insoles yearly, this makes it reasonable to say that the sensors are properly adjusted. See appendix A5 for the Certificate of Calibration. For this reason only the differences of the pressure distribution between measurements will be looked at in the next research.

The found results in this study of the static measurement with weights are as expected. In a similar study, an average correlation of 0.998 was found (Koch et al., 2016). In this study, an average correlation of 0.995 was found. One limitation in this study was that the available weights in stock reached only a total amount of sixty Kg. This is less than the average weight of the used subjects (71.9 Kg). If this study should have been executed with heavier weights the expectation would be that the correlation remains above 0.99. Koch et al. (2016). measured the Medilogic insoles up to a weight of eighty Kg. The correlations remained above 0.99.

When a person stands statically central on the whole foot or on the front of the soles, the correlation is above 0.8. The correlations of the back, lateral side and medial side are not higher than 0.8. It can be that the subject did not perform the positions correct. Standing on the toes or central are common positions, the other positions are rare. It can be that the subjects performed the rare positions differently which gives different values. This can influence the correlations. This may be the reason why the correlations for the common positions are high and the correlations for the rare positions are low.
It is also notable that the differences between left and right for heels and lateral for both of the shoe sizes are big. For standing on the heels for size 39/40, the difference is 0.34 and for lateral the difference is 0.177. For size 43/44 applies 0.378 and 0.342. This could be occurring because of the reason above. It could be that most of the people performed one side better than the other. Maybe this is due to the same preferred leg. This element is unknown so this is only a prognosis.
If this research should be performed again, the measurement protocol has to be changed so that the subjects perform the positions identically. A certain elevation underneath the heel while standing on the toes or an elevation underneath the forefoot while standing on the heels could be a solution.

In the dynamic measurement with subjects the correlations are not higher than 0.8. An explanation for the differences in the correlation could be:

- During walking the insoles can curl or shift underneath the foot. The curling of the sole can give extra pressure on certain places. Shifting the sole can cause the sole to be not in contact with the foot in some places and thus no pressure is recorded. These problems cannot be measure by the Kistler force plate. A solution to this problem could be to fix the insole to the foot or in the shoe. A suitable option for further research should be found.
- Sensors register pressure only when pressure works on the middle of the sensor. For this reason, some sensors may not be included in the measurement. These problems do not occur with measurements with the Kistler force plate.
- The shape of the foot is different for every subject. As a result, the area occupied by the foot on the sole is different per subject. The force is calculated based on the entire surface of the sole and not based on the occupied area of the sole. See figure 5.1. This problem only appears for the Medilogic insoles. These problems do not occur with measurements with the Kistler force plate.

Figure 5.1: Different shapes of a foot

The amplification factor would initially be used to adjust the data obtained from the static test with subjects and the dynamic test with subjects. After using this factor from the data of the Medilogic insoles it should be somehow equal to the data of the Kistler force plate. However this did not appear to be the case. The values of the Medilogic insoles were found to be further away from the Kistler force plate than without the amplification factor. Therefore, in consultation with the supervisor of the TCSAS, it is decided not to use the amplification factor while processing the data.

In this validation study two shoe sizes are measured. Due to the short period, only two shoe sizes were chosen. The shoe sizes 39/40 and 43/44 are chosen because they are common for men and women. A statement about the validity of the other insole sizes cannot be made because they have not been tested.

6. Conclusion I

The values of the Medilogic insoles are not consistent with the golden standard force values measured by the Kistler force plate. To find chancing patterns of the pressure distribution on the foot the Medilogic soles are suitable. See appendix A5.

The predefined main question 'Are the pressure values given from the Medilogic insoles consistent with the golden standard force values measured by the Kistler force plate.' can be answered with no. When a static object is placed on the pressure sole, the correlation for both shoe sizes both left and right is above 0.99.
The average correlations for both static measurements with subjects and in the dynamic measurement with subjects are not higher than 0.8. When a person stands statically central on the whole foot or on the front of the soles, the correlation is above 0.8.
The correlations of the back, lateral side, medial side and the dynamic test are not higher than 0.8.

Concluding, the Medilogic insoles are accurate for static weights. As soon as measurements are performed with persons the soles are not accurate for determining the absolute amount of the force. The mutual pressure distributions in the sole can be measured.

7. Analysis

The pre-study is finished. Before the main question can be answered a ramp will be designed following the preconditions and demands. The demands are obtained by the following analysis.

7.1. Inclination of the ramp

For hiking, there are three levels of difficulty. Slopes between 0% - 6% are considered easy. Slopes between 6% - 12% are considered as moderate and slopes over 12% are considered as difficult (Tiroler Landesregierung, sd).
In this study, an inclination of 12% was chosen as this way a big group of people will be able to walk up and down an imitated inclination of an outdoor slope.

7.2. Ratio between fore- and rear foot.

For this research, the foot was needed to be divided in two parts. The differences between the anterior- and the posterior part of the foot was looked at. The human foot is normally divided into three parts namely forefoot, midfoot and rear foot (Yung-Hui & Wei-Hsien, 2004). In this study the foot had to be divided into two parts. The program LabVIEW could divide the foot into two separate sections only. The ratio between fore- and rear foot is chosen to be 57% - 43%. The separation of the foot was established distal from Os naviculare. See figure 7.1.

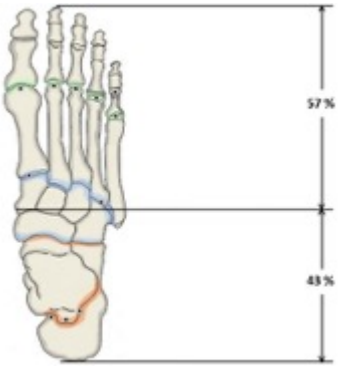


Figure 7.1: Ratio between the fore– and rear foot. Separation at Os naviculare

With this re-arrangement, the force and time from heel contact until midstance and midstance until toe off can be calculated separately.

7.3. Dimensions of the force plate

At the TCSAS there were two types of force plates available. One force plate was embedded into the floor (90x60 cm). The other force plate was portable (60x40 cm). The dimensions of the portable force plate needed to be taken into account for the design of the ramp, because the ramp will be used for other researches.

7.4. Dimensions of the lab

The lab had a limited space around the force plate. In figure 7.2 the available space around the force plate is shown. The area within the white marked lines was available space for the ramp. The surface is 3.50 m by 8.70 m. The ramp could not be bigger than these dimensions.

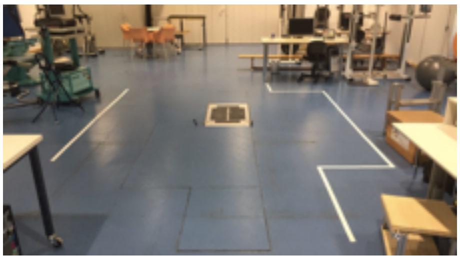


Figure 7.2: Maximum available lab space. The white lines indicates the boundaries

7.5. Force on the construction

The construction had to hold the weight of one person during walking. The applied force during level running could go up to 2,5 x the bodyweight (Keller, et al., 1995). The forces of running were used for safety reasons. The mean weight of a Dutch man is 83 Kg (SD 13) (TU Delft, 2004). 95% of the population had to be able to walk safely across the ramp without it breaking. A weight of 104 kg was calculated as the maximum weight for 95% of the population.
To summarize, the ramp should be able to hold the force of: $2{,}5 * (104 * 9{,}81) = 2550{,}6 \text{ N}$

7.6. Weight of the construction

The National Institute of Occupational Safety and Health (NIOSH) has created a so-called NIOSH-method. Hereby the weight of an object is determined depending on the distance of the displacement, the frequency, the rotation of the body and the height to the floor. The standard maximum weight is 23 Kg, but under rough circumstances it may be lower. In general, the outcome is no more than 12 Kg. (Ministerie van Sociale zaken en Werkgelegenheid, 2010)

Because the ramp construction is often set up and moved within a day the individual parts cannot weigh more than 12 Kg.

8. Preconditions and demands

The preconditions came from researchers from the OutFeet project and the limitations of the TCSAS. Previously, an analysis phase was done to give value to the preconditions, those are called demands.

8.1. Preconditions

- The weight of the ramp had to be as low as possible so it was easy to move.
- The construction had to be strong enough to hold the weight of a walking person.
- The ramp had to fit into the lab of the TCSAS.
- The dimensions of the portable Kistler force plate need to be taken into account so the middle part will fit on the force plate.
- The ramp had to have the ability to be adjusted and to change the inclination angle, with a maximum of 20% inclination.
- The cost of the ramp had to be as low as possible.
- The Medilogic insoles had to be used.
- The subject must feel safe walking on the ramp.

8.2. Demands

- The weights of the parts of the construction needed to be <12 Kg.
- The ramp must hold a force of 2550,6 N.
- The ramp has to be no bigger than 3.50 m by 8.70 m.
- The ramp consists of three parts.
- The middle part has the dimensions 59 cm x 28 cm.
- The ramp must have an inclination angle of 12%.
- The ratio between the fore and rear foot is 57%-43%.

9. Design

Three important conditions needed to be taken into account while designing the ramp:

- The ramp must have an inclination of 12%.
- The inclination percentage must also be changeable.
- The ramp must be used on top of the Kistler force plate.

To be able to measure the forces applied during the step, the ramp had to be divided into three parts. Because of this solution the middle parts could be fully placed on the Kistler force plate. The forces that worked on the foot were transferred to the Kistler force plate via the construction, in this way the force flow of one footstep could be measured. The ramp had to be designed so that other steps do not have any influence on the Kistler force plate. If the ramp is not divided into three parts but consists of one part, the forces would be divided on the poles of the ramp which are on the ground and outside the force plate. This way here would not be possible to measure the forces with the force plate (Wannop et al., 2014).

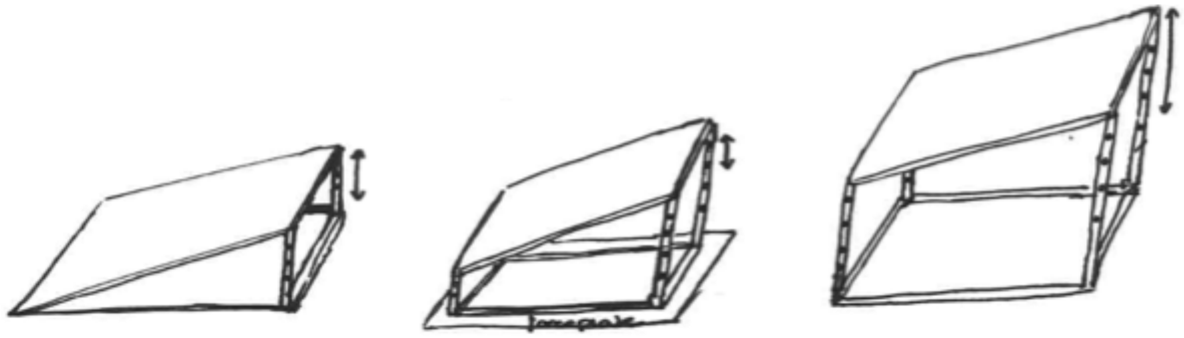


Figure 9.1: Three-piece ramp, adjustable in height and inclination percentage. The middle part stands on the Kistler force plate

To lower the costs of the construction, the use of item parts was advised. Item parts are squared pipes with a profile, see figure 9.2. The TCSAS owned a lot of standard item profiles. A concept was created out of item parts. Due to the profile of the item parts, the connecting and shifting of the parts is easy. If this concept satisfies the demands, no further concepts need to be created.

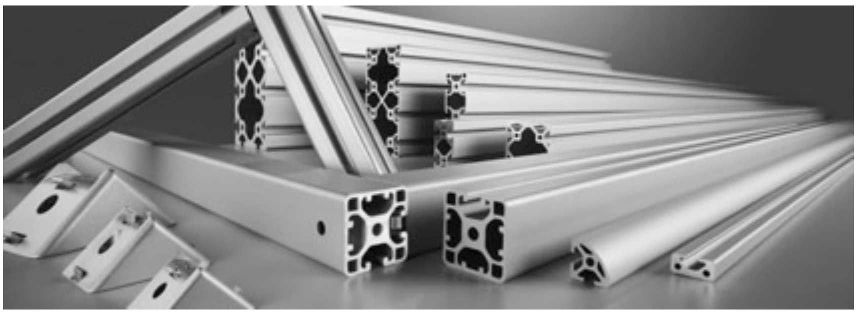


Figure 9.2: Item profiles. They are available in different material, shapes and lengths.

9.1. Concept

This concept was based on Item profiles. Through the 90° connectors the centre beam is able to adjust step less. To connect the profiles to each other or to attach any other components to the profile construction, movable nuts were used to fixate parts. The moveable nuts were used in the Item profile grooves. The top plates were fixed using a hang on system with hooks underneath. Figure 9.3 till 9.6 shows the development from brainstorm to concept.

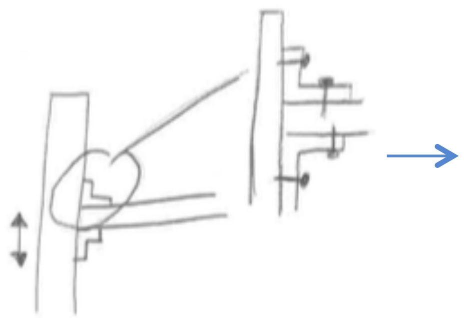


Figure 9.3: Brainstorm sketch of Item profile

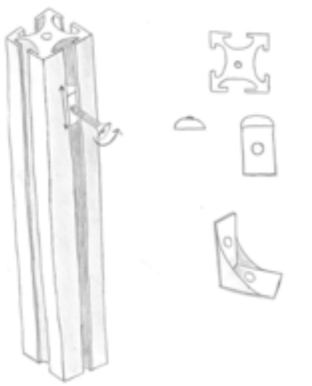


Figure 9.4: More detailed sketch of Item profiles

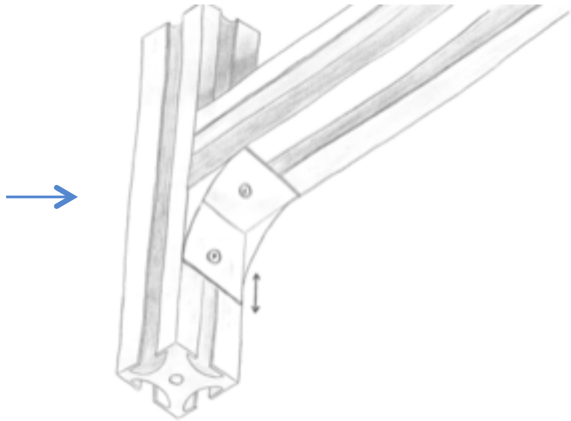


Figure 9.5: Item profiles used in a construction

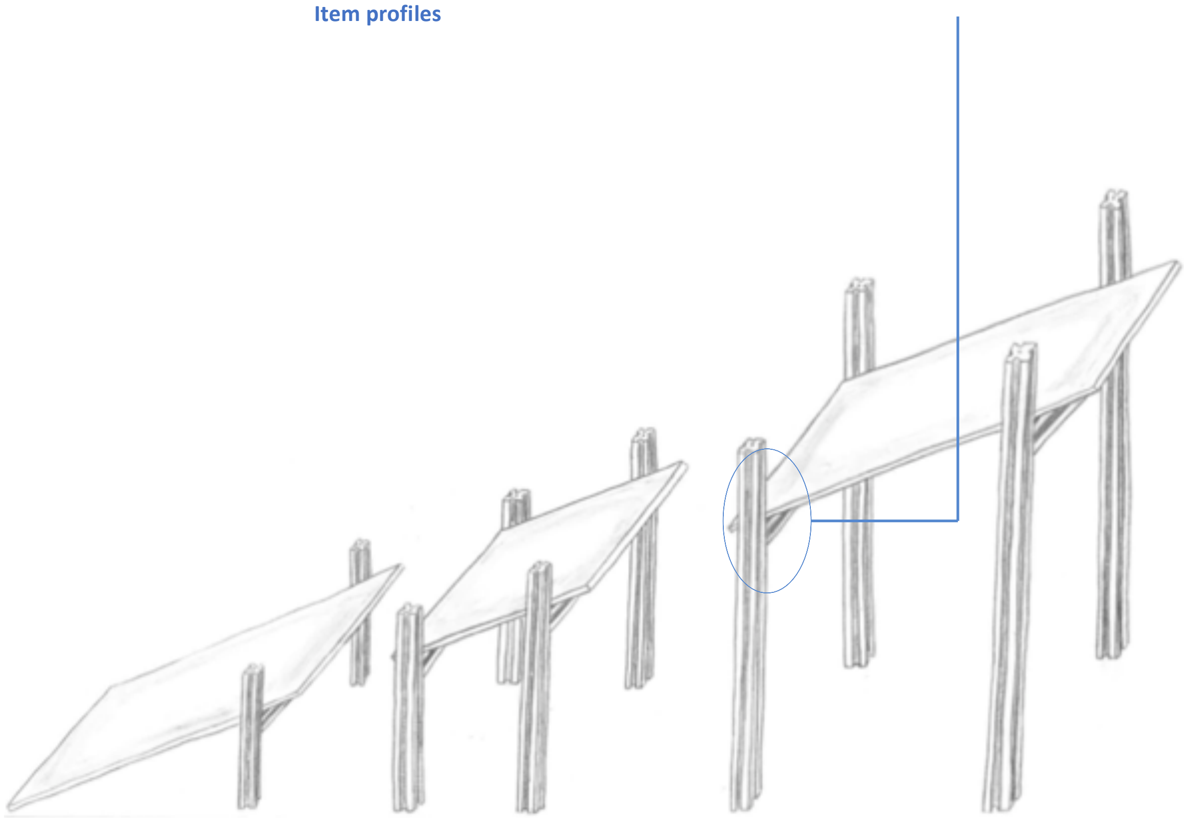


Figure 9.6: Concept, Item profiles

9.2. Proof of concept

In order to check if the concept meets with the preconditions and demands, they are taken into account. The positive and negative components are discussed in this chapter. Later on the concept is designed into a final concept.

Not all preconditions and demands were included during the evaluation process. Some of the preconditions and demands did not apply to the design of the ramp.

The preconditions and demands are discussed one by one:

1. The weights of the parts of the construction needed to be <12 Kg.

The lower part consists out of two objects, one support system and a top plate. The support system holds the plate. The middle part is a non-adjustable and solid part, but it is an open and small construction. The higher part consists out of two support systems to hold the top plate on both sides. Because the ramp is divided in this many separate parts, the weight of each part does not weigh more than 12 Kg.

2. The ramp must hold a force of 2550,6 N to hold the weight of a walking person.

The item profiles are made of anodized aluminium. This should be able to hold the maximum force of 2550,6 N. The top plates are made from wood. To prevent the plates from bending, material such as Item profiles have to be placed under the wooden plates. To be sure, calculations were done to see if the profiles were able to hold the force.

The amount of bending and the stress of bending on the critical points of the construction were calculated. In the lower part of the ramp, the locations where the most bending appeared are in the middle of the top plate and in the middle of the moveable profile which is holding the top plate.
In the higher part of the ramp, the locations where most bending appeared are at the same points as in the lower part. The only difference is that the higher part consists of two supporting systems. For those locations, calculations were done to examine whether the maximum bending stress stays underneath the maximum permissible stress.

The maximum permissible stress of an extruded aluminium profile is 120 N/mm^2. The permissible stress is calculated out of the yield point. The yield point is the point when the material begins to deform. For safety issues 70% of the yield point is within the permissible stress boundary (Broeren, 2017).

An automatic calculation system was used. The length of the profile and the force that works on the profile needed to be entered into the system used in figure 9.7 till 9.9.
The maximum lengths of the moveable profiles were calculated, the lengths are the same for the lower and the higher part of the ramp. Assuming that the maximum force on the moveable part is 2550 N, a length of 845 mm stays under the maximum permissible bending stress. Figure 9.7 shows the calculation.

With a length of 845 mm and a force of 2250 N a bending of 5,11 mm and a maximum bending stress of 119,71 N/mm^2 was calculated (Item, HABERKORN, 2017). The maximum permissible stress is 120 N/mm^2, so the moveable profile cannot be longer than 845 mm to be able to hold the weight of a walking person safely.

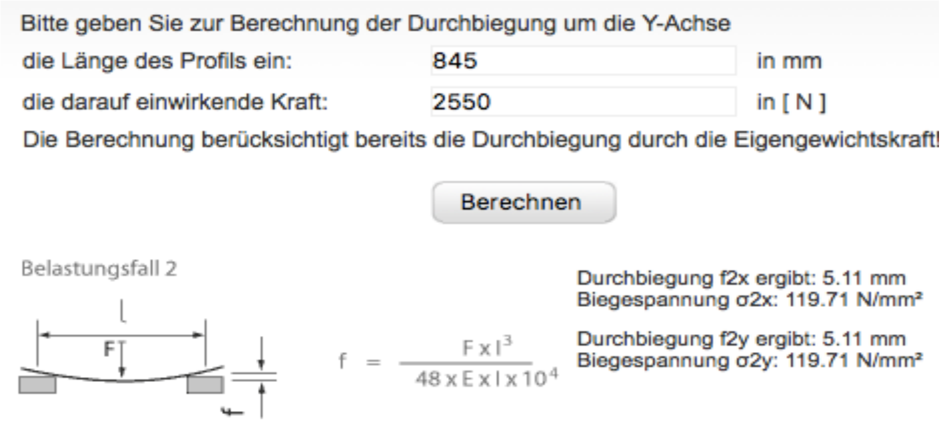


Figure 9.7: Standard calculations from Item website. With a maximum force of 2550 N, a length of 845 mm is still expectable.

Item profiles have to be placed under the wooden top plate to prevent from bending. The length of the profile can be maximal 2000 mm because of the standard length of the wooden plates. A minimal of three profiles have to be placed under the construction to stay under the allowed bending stress of 120 N/mm^2. Figure 9.8. shows the bending when using one profile. The bending stress of 283.33 N/mm^2 is more than the allowed bending stress. This will not hold a person walking on the construction.

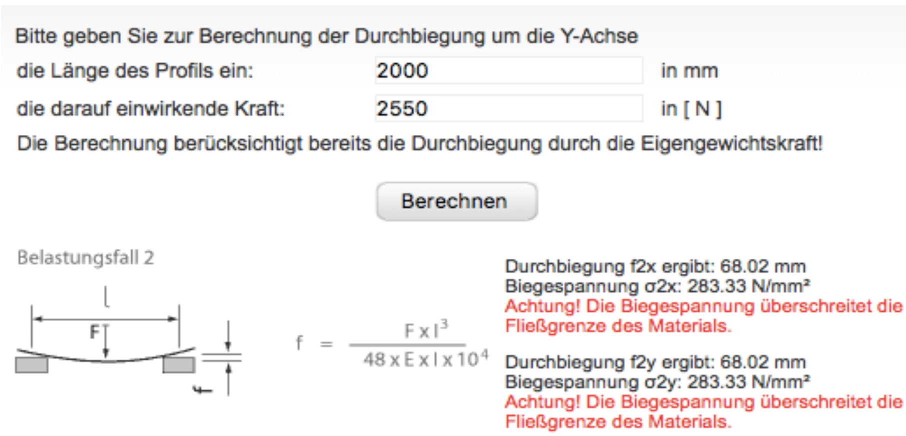


Figure 9.8: Bending calculation when using only one supporting profile. The used force will bend the supporting profile permanent.

Figure 9.9 shows the bending when using three profiles (2550 N / 3 Item profiles = 850 N per Item profile). With a bending of 23,5 mm and a stress of 94,44 N/mm^2 the bending stress stays under the maximum of 120 N/mm^2.

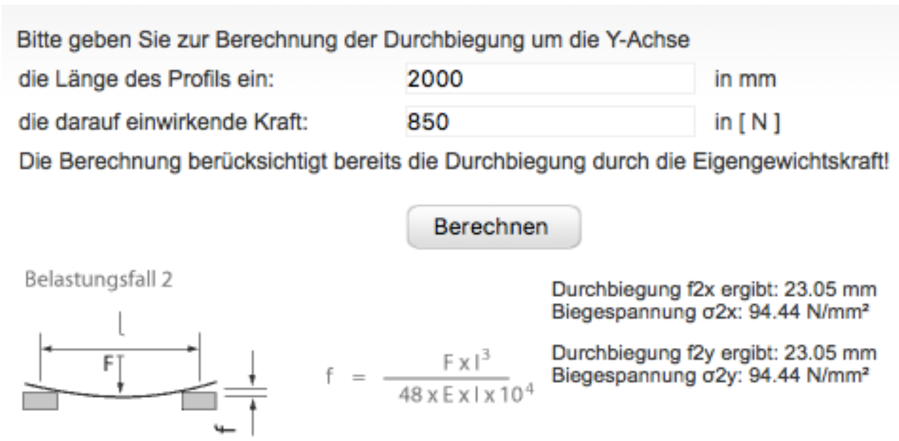


Figure 9.9: Bending calculation when using three supporting profile. With three supporting profile, the bending stress stays under the limit.

Summarizing, if the moveable profiles are no longer than 845 mm and if under the wooden top plate three supporting profiles are placed, it is safe to say that the construction is strong enough for the measurements.

3. The ramp has to be adjustable in different inclination angles, with a maximum of 20% inclination. For this research, the angle has to be set on 12%.

Because of the Item profile connecting and shifting parts is easy. To know the minimum height of the construction, calculations have to be undergone.

Because wooden plates of 2000x500 mm were available at the TCSAS, these had to be used for the construction of the ramp.

The lower part of the ramp:
The top plate has dimensions of 2000x500 mm. The end of the plate has to be extended a bit to merge in with the next part. Important is that the both parts do not touch each other, because of the force distribution on the Kistler force plate. The inclination of the first part has to go up until a maximum of 20%. 20% = 11,31°. The height is calculated by the following formula: $\sin x * length = height$.
$\sin 11{,}31 * 2000 = 392{,}23\ mm$, see figure 9.10.

Figure 9.10: Indication of the maximum height of the first construction.

Figure 9.11: Indication of the maximum height of the support construction with an inclination of 20%.

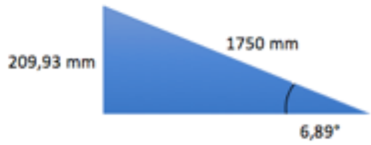


Figure 9.12: Indication of the height of the support construction with an inclination of 12%.

Assuming that the extended part will be 250 mm, the distance between the beginning of the plate and the end of the supporting part will be 1750 mm (2000-250=1750 mm). By an inclination of 20% the height of the supporting part has to be: $\sin 11{,}31 * 1750 = 343{,}21\ mm$. The side poles of the support construction of the lower part must have a minimum length of 350 mm, see figure 9.11.

The height of the construction for 12% is calculated to set the moveable profile on the right height of this research. 12% = 6,89°: $\sin 6{,}89 * 1750 = 209{,}93\ mm$. The support construction of the lower part must be set on 210 mm, see figure 9.12.

The middle part of the ramp:
The same calculations are made for the middle part of the construction.
The side poles on the front of the construction must have a minimum height of 392,23 mm.
For a 12% inclination the construction must be set on 239,93 mm.
The side poles on the backside of the construction must have a minimum height of 492,25 mm
For a 12% inclination the construction must be set on 301,11 mm

The higher part:
The same calculations are made for the higher part of the construction.
The side poles of the first support construction must have a minimum height of 541,28 mm.
For a 12% inclination the first support construction must be set on 330,75 mm.
The side poles of the second support construction must have a minimum height of 884,49 mm
For a 12% inclination second support construction must be set on 540,69 mm.

4. The costs for the ramp have to be as low as possible.

Most of the materials to build the ramp are already owned by the TCSAS, therefore there is no need to buy new materials. This reduces the costs.

5. The subject must feel safe walking on the ramp.

The ramp has to be stable and the bending of the top plates has to be as little as possible. By using the supporting profiles underneath the top plates the bending will appear no more than 23,05 mm. To stabilise the construction, support profiles have to be placed on the side of the side poles. Safety mats have to lie around the ramp during the final measurements as well.

Overall the concept meets the previous discussed demands. Therefore, there was no need to create other concepts. Out of the previous calculations new demands arose. These were used to design the final concept. The new demands are:

- The construction has to be made out of Item parts
- The side poles of the support construction of the first part must have a minimum length of 350 mm.
- The support construction of the first part must be set on 210 mm.
- The side poles on the front of the second part must have a minimum length of 392,23 mm.
- The front construction of the second part must be set on 239,93 mm.
- The side poles on the backside of the second part must have a minimum length of 492,25 mm.
- The back construction of the second part must be set on 301,11 mm.
- The side poles of the first support construction of the third part must have a minimum length of 541.28 mm.
- The first support construction of the third part must be set on 330,75 mm.
- The side poles of the second support construction of the third part must have a minimum length of 884,49 mm.
- The second support construction of the third part must be set on 540,69 mm.
- For safety issues mats have to be placed around the ramp while walking across the ramp.

9.3. Final design

9.3.1. Solidworks drawings

A number of changes have been made to meet the preconditions and demands. These changes led to the final design. This final design is drawn in the design software program Solidworks, see figure 9.13. Blueprints of the whole construction and the different parts were placed in the appendix A6.

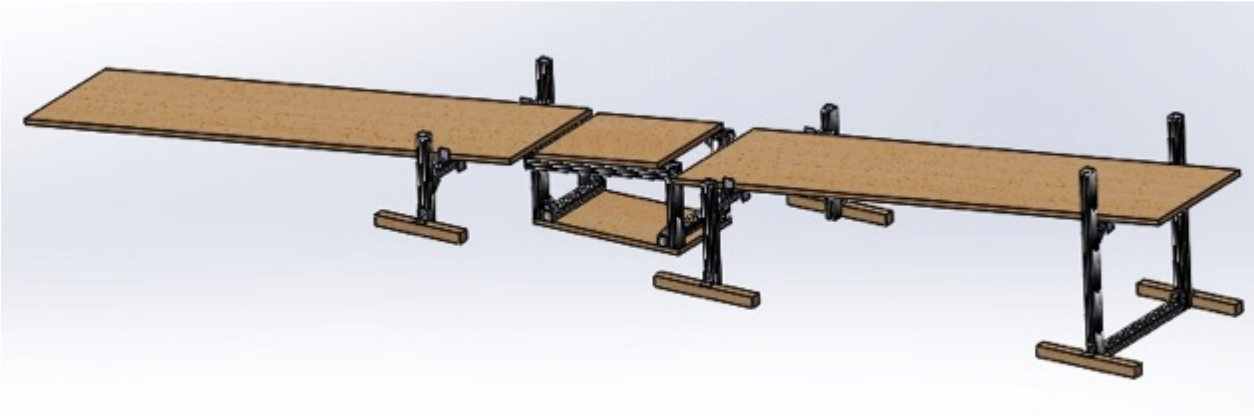


Figure 9.13: Solidworks drawing of the final design, side view

9.3.2. Physical design

After the virtual design a physical design was constructed, see figure 9.14. A number of additional elements were added while making the ramp. Rubber was placed underneath all the poles of the construction. In this way the floor of the laboratory would not be damaged and the construction would not slip away when walking over it.

Figure 9.14: Total construction, side view

More pictures of the total construction and the different parts can be found in appendix A7.

10. Method II

The final measurement was done on the designed ramp. The protocol will be discussed in this chapter. This protocol is written to find differences between uphill, downhill and level walking in the Medilogic insole data. Different parameters were looked at:

- Total time step time.

The total step time was evaluated because it is presumed that there is a difference between uphill, downhill or level walking. It is assumed that the total step time is longer when walking uphill, because it takes most effort. Level walking takes the least effort. Therefore level walking is likely to be the fastest.

- Time difference between the beginning and the maximum force of the posterior phase.

This parameter gives an indication of the time period of HC until the moment of total load on the posterior part of the foot. Due to gravity it is more likely that the time period of this phenomenon is higher when walking downhill. Because it takes more effort to roll the foot when walking uphill it is assumed that the time period is the shortest. For level walking the time period should be in-between uphill and downhill.

- Time difference between the maximum force of the posterior phase and the intersection.

This parameter gives an indication of the time period to roll over until midstance. The same reason and hypothesis of the time difference between the beginning and the maximum force of the posterior phase applies to this parameter.

- Time difference between the intersection and maximum force of the anterior phase.

This parameter gives an indication of the time period between rolling from midstance to TO. When walking uphill the period a subject stays on the anterior part of the foot before leaving the ground is more likely to be the longest. Assuming the subject needs to put more effort into rolling the foot, the subject requires a longer time to roll to the toes. Because of gravity the period of the anterior phase for downhill walking is expected to be the lowest. For level walking the time period should be, again, in-between uphill and downhill.

- Ratio between the height of the peaks.

The ratio is the proportion in which the one is bigger in comparison to the other. When a ratio of 1 is found then the values of the parameters are equal. It takes more strength to unroll the foot and walk uphill. Therefore it is likely that the peak value of the anterior phase is higher than the peak of the posterior phase (ratio >1) by walking uphill. It is expected to be the other way around for walking downhill (ratio <1). Due to gravity it does not take a lot of strength to unroll the foot. Because of that the maximum force of the posterior phase is expected to be higher. For level walking it is assumed that the anterior phase gives a higher peak because the subject needs to take off with more force. This requires less strength than walking uphill. This is why the ratio should be closer to one than the ratio for uphill walking.

- Ratio between the width of the anterior- and posterior phase.

This parameter indicates if the time the subject stays on one part (anterior/posterior) longer than the other. For downhill walking it is predicted that the subject stays longer on the anterior phase. A person is inclined to roll to the toes quicker when walking downhill. It is assumed that the period in which the subject spends on the posterior part of the foot becomes longer when the inclination changes from downhill to uphill. It will take more effort to go from the posterior part to the anterior part of the foot.

Whether these hypothesises are correct and if this shows significant differences, measurements had to be done first.

10.1. Protocol

10.1.1. Subjects

The same subjects who participated in the previous study (validation study) participated in this study as well. More information about the subjects is written in chapter 2.1.1.1. Appendix A2 gives an overview of the personal related information collected from the subjects. The subjects were previously informed about the purpose of the study by an information letter (see appendix A8).

10.1.2. Measurement equipment

10.1.2.1. Previously used equipment and measurement systems

For this study the same Adidas indoor shoes from the previous study were used. Chapter 2.1.1.2 discussed more information about the shoes. The Medilogic insoles and the Kistler force plate were used in this study too. In chapter 2.1.1.3 and 2.1.1.4 the working of the Kistler force plate and the Medilogic insoles is described.

10.1.2.2. Lukotronic

The Lukotronic AS202 is a motion capture system which consists of a bar with three infrared cameras and active markers which are worn by the subjects on anatomical reference points. These markers send out infrared light and the cameras detect the light. A stick figure appears in the Lukotronic software. The frequency in which the Lukotronic measured was 30 Hz. See figure 10.1 for the Lukotronic system.

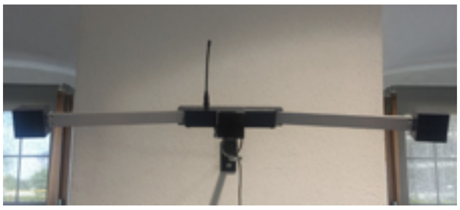


Figure 10.1: Lukotronic motion capture system. An infrared camera is placed left, middle and right in the black areas on the picture.

10.1.3. Ramp

The ramp was built of Item- and wooden components. The ramp consisted out of three parts.
The lower part was necessary to walk up to height of the middle platform. The middle platform was standing on top of the force plate. The higher part was necessary to continue walking at the same speed after stepping on the force plate platform. See figure 10.2.

Figure 10.2: Ramp setup in lab.

The higher and the lower parts were adjustable in height because of the item components. The ramp is built and designed with an inclination of 12%. The ramp can be adjusted to an inclination of up to 20%. For safety issues mats were placed around the ramp during the measurements.

10.1.4. Requirements

- Ramp with 12% inclination.
- Medilogic insoles (size EU 39/40 & EU 43/44).
- Adidas indoor shoes (size 39, 40, 43 & 44).
- Kistler force plate.
- Lukotronic.
- Active marker string with five markers.
- Tape.
- 6 safety mats.
- Backpack.

10.1.5. Measurement

10.1.5.1. The measurement

The Medilogic insoles are used to look at the differences of the pressure distribution between measurements. Why the Medilogic insoles are suitable to measure this is discussed in chapter 5.

Three different measurements were performed: uphill, downhill and level walking. Each subject performed five walking trails for each measurement. To establish the starting point the subject had a moment to practise walking on the ramp.
In order to have as few variables as possible, it was decided to let the subject step on the force plate with their right foot (Wannop, Worobets, Ruiz, & Darren, 2014).
The Lukotronic was fixed to the wall (see figure 10.1). Because only the right foot was measured, the entire ramp had to be rotated 180 degrees when the walking direction changed. There was a limited time for the measurements due to the occupation of the lab for other studies.
Therefore it was not time efficient to randomize the order of the measurements.

For project OutFeet data was collected from the Medilogic insoles, the Kistler force plate and the Lukotronic motion capture system. For this study only the data of the Medilogic insoles will be used and discussed. In further research they will look at the data from the Kistler force plate and the Lukotronic.

10.1.5.1.1. Setting subject

The subjects needed to be set up with the measurement equipment before the measurements took place. The subject was wearing tight clothes. The Medilogic insoles were placed in the Adidas indoor shoes and fixed to the leg and shoulder of the subject. The active markers were placed on anatomical reference points of the right side of the subject. The anatomical reference points are (the numbers on figure 10.3 represent the numbers of the reference points):

1. Tuberositas ossis metatarsalis V.
2. Malleolus lateralis.
3. Epicondylus lateralis of the femur.
4. Trochanter major of the femur.
5. Acromion.

The subjects wore two transmitters on the waist, one of the Medilogic insoles and one of the Lukotronic. The subject was wearing an empty backpack. The subject needed to hold the shoulder straps during walking, to prevent the arms from swinging in front of the active markers. See figure 10.3 for the setup.

Figure 10.1: Subject with sensors. From bottom up 1 till 5. Numbers refer to the reference points.

10.1.5.1.2. Level walking

The subject walked directly on the laboratory floor. The start position was two steps in front of the force plate. In this way the third step with the right foot was directly on the force plate, which was embedded in the floor. The subject walked two more steps after the right foot stepped on the platform. Then the subject closed the step. This counted as one measurement. The Kistler force plate and the Lukotronic were combined in one software program. This software will start the measurement for both of the measurement equipment at the same time. After the Kistler force plate and the Lukotronic were set on recording the Medilogic insoles were started. As soon as all three of the devices were measuring the subject got a signal to start walking. After the second step on the higher platform the subject closed the step and stood still and the measurement was stopped. This measurement was done five times in a row.

10.1.5.1.3. Walking uphill

The subject started in front of the lower part of the ramp. The subject walked up hill and had to place his or her third step with the right foot on the force plate platform. To make sure that this step is obtained during a constant walking speed the subject continued walking for two more steps to the top of the ramp. After the closing last step the subject stood still and the measurement stopped. This measurement was done five times in a row. The starting and stopping of the measurement was done as described in 10.1.5.1.2.

10.1.5.1.4. Downhill walking

The subject started on top of the ramp. The subject walked down hill and had to place his third step with the right foot on the force plate platform. To make sure that this step is obtained during a constant walking speed the subject continued walking for two more steps. After the last step the subject stood still and the measurement stopped. This measurement was done five times in a row. The starting and stopping of the measurement was done as described in 10.1.5.1.2.

10.1.5.1.5. Vocal Instructions

‘We are going to do three measurements.’ ‘I will explain them one by one’. ‘The first measurement is easy, you are going to walk back and forth for 5 times across the force plate.’ ‘Before your foot touches the force plate you walk two steps and after the force plate you walk two steps more.’ ‘Make sure that your right foot steps on the platform.’ ‘At the end, you close your step.’ ‘You stand still for five seconds.’ ‘If you get a sign from us, turn around and walk back to the starting point.’ ‘On our sign you can start walking again.’ ‘We do this five times.’ ‘Important is that you will hold the shoulder straps of the backpack during the measurement.’ ‘I will show you how to do it.’ ‘You have to practice until you feel secure walking.’

‘The second measurement.’ ‘Make sure that your third step is on the force plate platform with your right foot, and continue walking for two more steps.’ ‘Close you step and stand still, we’ll stop the measurement.’ ‘Important is that you will hold the shoulder straps of the backpack during the measurement.’ ‘Subsequently you walk down the ramp, this will not be a measurement’. ‘When you walked down the ramp, you turn 180 degrees and then we start a new measurement.’ ‘We do this five times.’ ‘I will show you how to do it.’ ‘You have to practice until you feel secure walking the ramp.’

‘The third measurement.’ ‘You walk up until the top of the ramp, and turn 180 degrees.’ ‘This will be the start position.’ ‘Make sure that your third step is on the force plate platform with your right foot, and after continue walking for two steps.’ ‘Close you step and stand still on the ramp.’ ‘This is the moment that we stop the measurement.’ ‘Make sure you hold the shoulder straps of the backpack during the measurement.’ ‘We do this five times.’ ‘I will show you how to do it.’ ‘You have to practice until you feel secure walking the ramp.’

11. Data processing II

11.1. Data processing with LabVIEW™ 2015

Chapter 3.1.1. gives general information about LabVIEW.
The data from the Medilogic insoles was loaded into LabVIEW. LabVIEW created a graph as shown in figure 11.1. Two signals were drawn, the anterior force and the posterior force. The anterior force (red signal) is the force which is working during standing on the anterior part of the foot. The posterior force (black signal) is the force that acts on the posterior part of the foot during standing. This separation between the fore- and rear foot was discussed earlier in chapter 7.2.

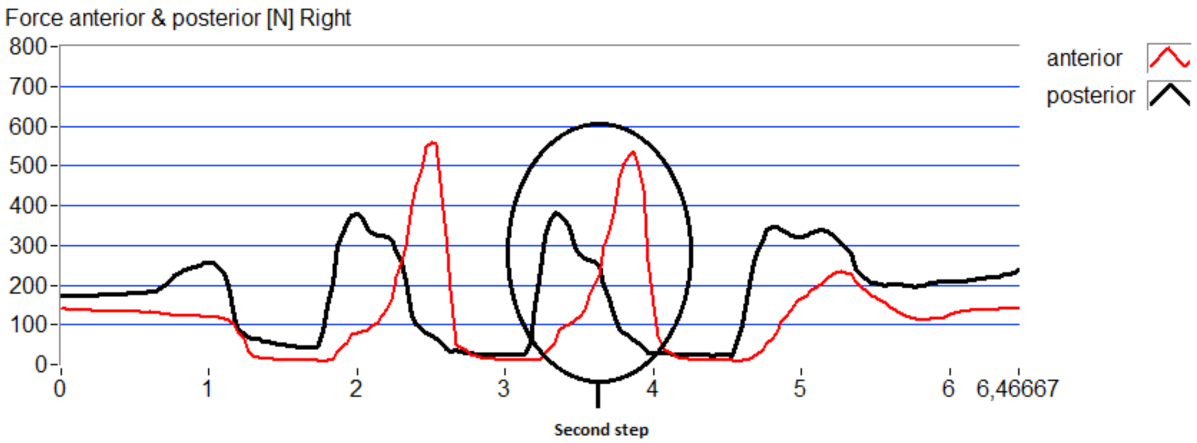


Figure 11.1: Anterior and posterior walking signal of the right foot of the Medilogic, force[N] vs. time[s].

The data of the second step was cut out. The cut out time of 1,5 second was used for every measurement. After cutting only the second step was shown. See figure 11.2.
This graph was exported as an .XLSX file. In total there were fifteen .XLSX files for every subject.

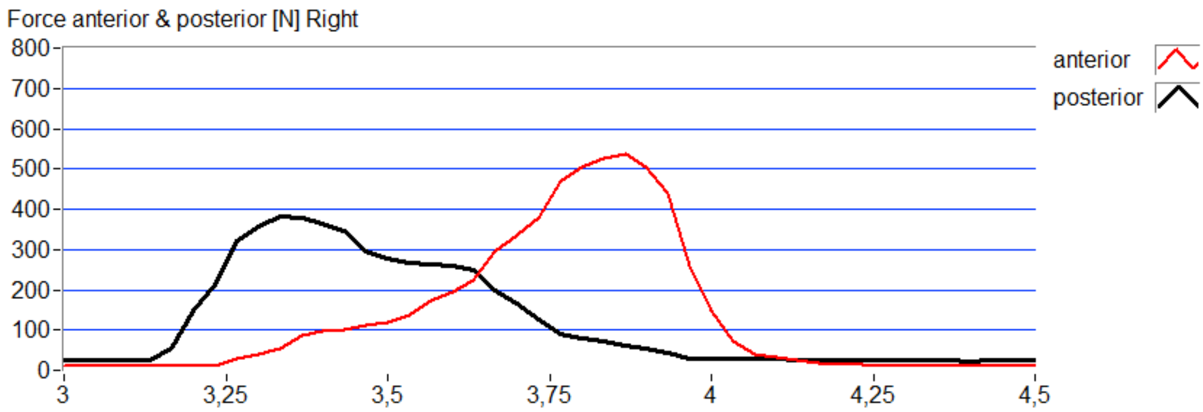


Figure 11.2: Cut signal to 1,5 seconds. Force divided in anterior and posterior force. Right foot from the Medilogic

The .XLSX files were loaded into MATLAB. MATLAB was used to determine reference points in the graphs. The uphill, downhill and level files, of the same subject, of the first measurement were loaded into MATLAB. For example Name-up-1, Name-down-1 and Name-level-1 were selected.

11.2. Data processing with MATLAB®, MathWorks 2015b

For further calculations reference points are used. The seven reference points are (the numbers on figure 11.3 refer to the numbers of the reference points):

1. The beginning of the posterior phase
2. The Maximum force of the posterior phase
3. The end of the posterior phase
4. The intersection of both graphs
5. The beginning of the anterior phase
6. The Maximum force of the anterior phase
7. The end of the anterior phase

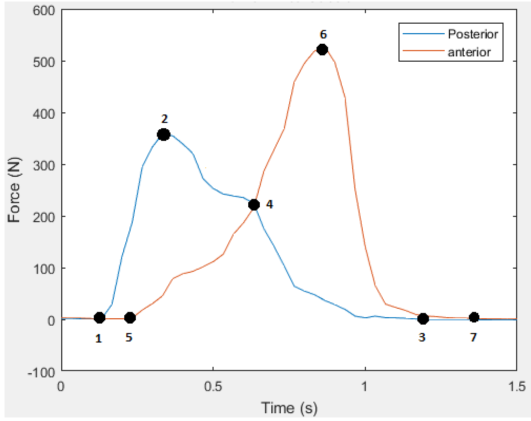


Figure 11.3: Reference points. The numbers refer to the reference points.

The maximum peaks were detected by MATLAB itself. The other five reference points assigned by clicking manually on these points. See figure 11.4.

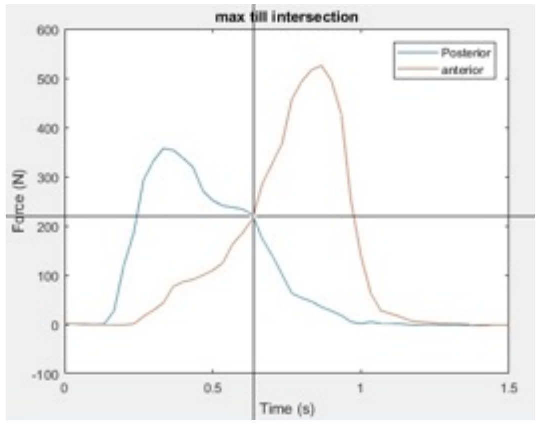


Figure 11.4: Manually determining reference points

The y-value of the beginning of the posterior phase and the y-value of the beginning of the anterior phase were used to calculate an offset. This is used to let the signal start at 0.

The reference points are also used to calculate the parameters.
The parameters are (numbers of the reference points from figure 11.3 are in parentheses):

1. Total step time (1-7)
2. Time difference between the beginning (1) and the maximum force of the posterior phase (2). This is phase 1 in figure 11.5.
3. Time difference between the maximum force of the posterior phase (2) and the intersection (4). This is phase 2 in figure 11.5.
4. Time difference between the intersection (4) and maximum force of the anterior phase (6). This is phase 3 in figure 11.5.
5. Ratio between the height of the peaks. This is calculated by dividing the y value of reference point 2 by the y value of reference point 6, see figure 11.3.
6. Ratio between the width of the anterior and posterior phase. This is calculated by dividing the time difference of phase 1 plus 2 by the time difference of phase 3 plus 4, see figure 11.5.

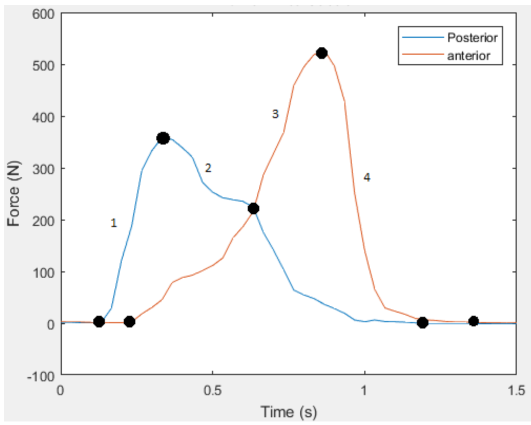


Figure 11.5: The four time phases of the parameters.

The values for the parameters obtained by MATLAB were exported to Excel. For every subject five documents with the values of the parameters were processed. A mean value for every parameter was calculated. These values were compared with SPSS.

11.3. Data processing with IBM© SPSS© statistics 24

One-way analysis of variance (ANOVA) is used to discover whether there is statistically significant difference between the means of two or more groups. Three groups were drafted in this study. Group 1 = uphill walking, group 2 = downhill walking and group 3 = level walking.

Before executing ANOVA, there were assumptions which must be complied first.
The first assumption was to check the normal distribution of the population. By executing the 'Test of normality', signification of the 'Kolomogorov-smirnov test' was shown. When the significance of all the groups were <0.05 was the data normal distributed and the assumption was approved.

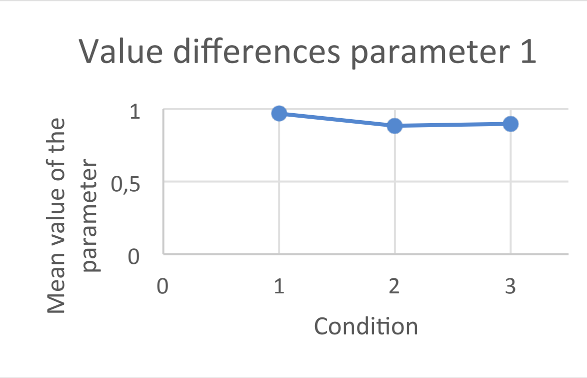
The Second assumption was to check if the variation within the groups were equal. The 'Homogeneity of variances test', so-called 'Levene Statistic', was used for that purpose. When the significant was >0.05, the ANOVA table was viewed. The ANOVA table showed weather there was an overall significance difference between the three groups.
When the significance of the ANOVA table was >0.05 there was no significance difference found. When the significance of the ANOVA table was <0.05 a significant difference between the three groups was found. To examine where and how much the difference occurred, the Post Hoc test in the category equal variance assumed, 'Bonferroni' was performed. This table showed the significance between each group.

When the first assumption (normal distribution of the population) was rejected, other tests were executed. The 'Friedman test' is the non-parametric alternative to the one-way ANOVA. The 'K Related Samples' performed the 'Friedman test'. The obtained 'Test Statistics' table showed weather there was an overall significance difference between the three groups.
To examine where and how much difference between the groups occurred, the 'Wilcoxon signed-rank tests' was performed. 'Bonferroni' was used manually to adjust the result from 'Wilcoxon signed-rank tests'. This was needed because there were made multiple comparisons, which increased the change of a type 1 error. The significance level (0.05), which initially was used for normal distributed data, was divided by the number of tests that were executed (in this case three: uphill & downhill, uphill & level and downhill & level). The new significance level was 0.05/3 = 0.017. If the p value was >0.017, there was no statistically significant result.

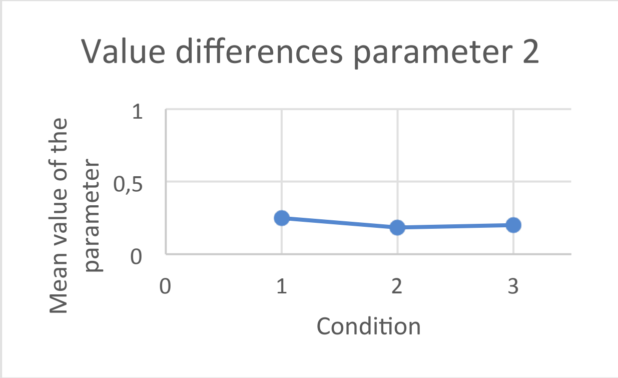
12. Results II

This chapter discusses the results of the measurements performed on the ramp. Three different conditions are compared. The conditions are uphill-, downhill- and level walking.

Graph 12.1 to 12.6 shows the spread of the mean values of the six different parameters. A relation between the three different conditions is shown. Condition 1 represents uphill walking. Condition 2 represents downhill walking and condition 3 represents level walking.

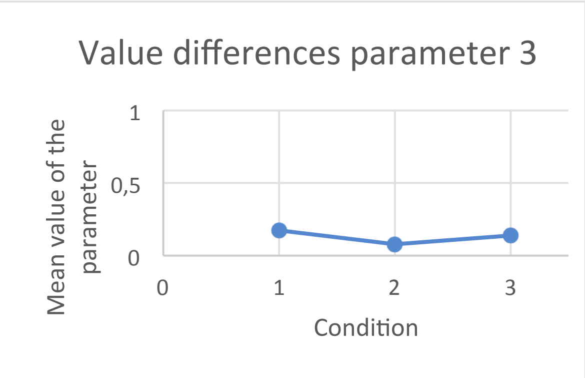


Graph 12.1: The spread of the mean values of parameter 1.

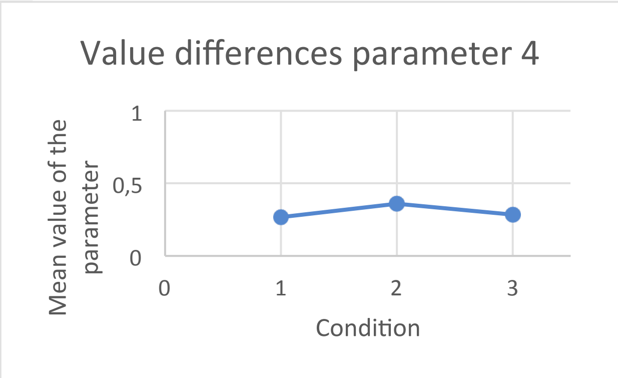


Graph 12.2: The spread of the mean values of parameter 2.

Graph 12.1 shows that the step time of uphill walking is the biggest followed by level walking. The step time for downhill walking is the shortest.
Graph 12.2 shows that the time period to get from HC to the moment of total load on the posterior part of the foot, is the longer for walking uphill, than level walking followed by downhill walking.

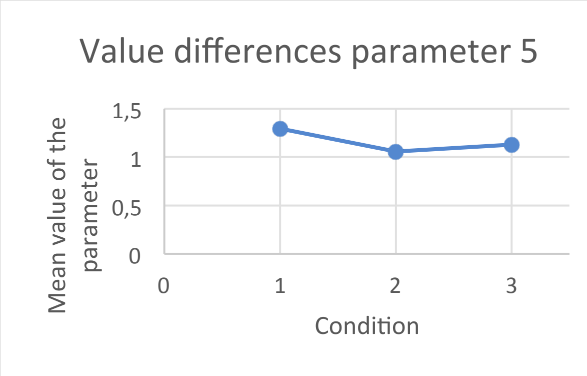


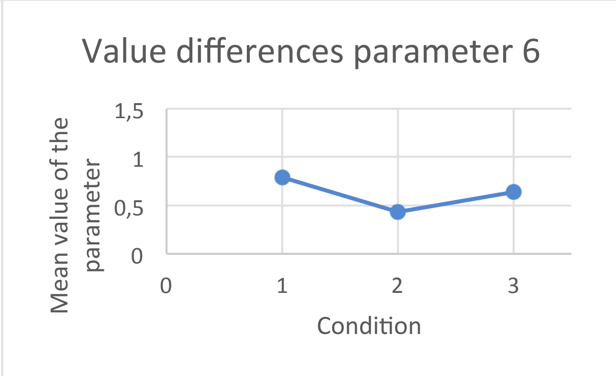
Graph 12.3: The spread of the mean values of parameter 3.



Graph 12.4: The spread of the mean values of parameter 4.

The time period from the maximum force of the posterior phase to midstance is for uphill walking the longest. Followed by level-, and downhill walking, see graph 12.3.
The time period from midstance to maximum force of the anterior phase is for downhill walking the longest. Followed by level-, and uphill walking, see graph 12.4.





Graph 12.5: The spread of the mean values of parameter 5. **Graph 12.6: The spread of the mean values of parameter 6.**

Uphill walking has the biggest ratio between the heights of the peaks. Following by level walking. Downhill has the smallest ratio between the peaks, see graph 12.5.
Uphill has the biggest ratio between the width of the anterior and posterior phase, downhill has the lowest ratio, see figure 12.6.

Two tables are given to see whether the differences are significant or not. Table 12.1 contains the results of the parameters that were normally distributed. Table 12.2 shows the results of the parameters that were not normally distributed. For table 12.1 there is a significant difference when this is <0.05. For Table 12.2 there is a significant difference when this is <0.017.

Table 12.2: Statistical differences of the normal distributed parameters. In chapter 10 explains the six parameters.

Statistical difference of the normal distributed parameters				
	Parameter 1	Parameter 2	Parameter 4	Parameter 5
Uphill & Downhill	0.040	<0.001	<0.001	0.350
Uphill & Level	0.109	<0.001	1.000	0.221
Downhill & Level	1.000	0.242	0.002	1.000

Table 12.1: Statistical difference for the not normal distributed parameters. Chapter 10 explains the six parameters.

Statistical difference of the not normal distributed parameters		
	Parameter 3	Parameter 6
Uphill & Downhill	0.005	0.005
Uphill & Level	0.028	0.059
Downhill & Level	0.005	0.005

- In parameter 1, One condition, between uphill & downhill was found significant.
- In parameter 2, two conditions, between uphill & downhill and uphill & level were found significant.
- In parameter 3, two conditions, between uphill & downhill and uphill & level were found significant.
- In parameter 4, two conditions, between uphill & downhill and downhill & level were found significant.
- In parameter 5, no condition was found significant.
- In parameter 6, two conditions, between uphill & downhill and uphill & level were found significant.

13. Discussion II

For all parameters a hypothesis was drafted. In some of the parameters a significant difference between the conditions was found. These parameters can be used to see if a person is walking uphill, level or downhill. All the conclusions relate only to an inclination of +12% (uphill), 0% (level) and -12% (downhill). Nothing can be said about the relation between the three conditions with other inclination percentages.

(Parameter 1) It was assumed that the total step time would take longer by walking uphill. Level walking was assumed to be the fastest. It appears that an uphill step indeed takes the longest time, however for downhill, the step time is the shortest. Only a significant difference (0.040) between uphill & downhill walking was found. The step time is only a good indicator to see if a person is walking uphill compared to downhill.

(Parameter 2) It was more likely that the time period between the beginning and the maximum force of the posterior phase was higher when walking downhill. Walking uphill was assumed to be the lowest. For level walking the time period was expected to be in-between uphill and downhill. The results show the biggest time difference for uphill, followed level walking and the smallest time difference for downhill walking. However only a significant difference (<0.001) between uphill & downhill walking and uphill & level walking was found. This parameter could be a good indicator to see if a person is walking uphill, further research has to be done to give an exact value to this parameter. This should work as a sort of threshold. If the time difference rises to a certain amount it can be assumed that the person is walking uphill.

(Parameter 3) It was more likely that the time period between the maximum force of the posterior phase and the intersection was higher when walking downhill. Walking uphill was assumed to be the lowest. For level walking the time period was expected in-between uphill and downhill. It appears that the time difference for uphill walking was the biggest, followed by level walking. Downhill walking was the shortest. However, there is only found a significant difference (0.005) between downhill & uphill and downhill & level. This parameter could be a good indicator to see if a person walks downhill, further research has to be done to give an exact value to this parameter for the same reason as described at parameter 2.

(Parameter 4) When walking uphill the period a subject stayed on the anterior part of the foot before leaving the ground is more likely the longest. The period on the anterior phase for downhill is expected to be the lowest. For level walking the time period was expected, again, in-between uphill and downhill. But as the results show the time period from midstance to maximum force of the anterior phase is the longest for downhill walking. Followed by level walking, uphill walking was the shortest. However, only a significant difference between downhill & uphill (<0.001) and downhill & level (0.002) was found. This parameter could be a good indicator to see if a person is walking downhill, further research has to be done to give an exact value to this parameter for the same reason as described at parameter 2.

(Parameter 5) It was assumed that the ratio between the peak values was the highest for walking uphill. Downhill walking was expected to be the lowest. Indeed, for uphill walking the biggest ratio is found, followed by level walking. Downhill has the smallest ratio between the peaks. However, no significant difference between the three conditions was found. This parameter cannot be a good indicator to see if a person is walking uphill, level or downhill.

(Parameter 6) For downhill walking it is predicted that the subject stays longer on the anterior phase. It is assumed that the period in which the subject spends on the posterior part of the foot becomes bigger when the inclination changes from downhill to uphill. This also appears in the results. The longer the person stays on the anterior phase in comparison to the posterior phase, the lower the ratio. Uphill also has the biggest ratio between the width of the anterior and posterior phase. Downhill has the lowest ratio and level is in-between. However only a significant difference (0.005) between downhill & uphill and downhill & level was found. This parameter could be a good indicator to see if a person is walking downhill. Further research has to be done to give an exact value to this parameter for the same reason as described above.

Generally reasons for the different outcomes can be that the inclination of the ramp was only +12% or -12%. It can be that the steepness of the ramp was to little to make a change in the walking patterns of the subjects. More research with a higher and lower inclination percentages should be done to see if the pattern remains. Another reason can be the small group of subjects. Data was collected only from a small number of subjects. Therefore outliers could have influenced the results. The outliers were not eliminated because of the few data.
The subjects walked with their preferred walking speed. This could also have caused differences in the data.

Differences in the data for parameter 1, 2 and 6 can also be due to the data processing. Whilst using MATLAB the reference points in the graphs, except for the maximum force of the posterior phase and the maximum force of the anterior phase, are manually applied. This is not a secure way of receiving the correct values. Especially when the steepness of the graph is low, the start or end of the graph is difficult to determine. This can cause differences in the data and can be the reason why there are no further significant differences.
Sensors register pressure only when pressure is put on the middle of the sensor. For this reason it could be that the HC was registered later than the initial contact. It could also appear that the actual TO-phase should have taken longer but the sensors did not register anything anymore.

14. Conclusion II

The main question of this research was: Which of the drafted parameters that work on the foot are significantly different at an inclination angle of +12%, 0% and -12% in comparison to each other.
For all the parameter has been found at least one significant difference with in the three different conditions except from parameter 5.

Parameter 1: total step time. The difference between uphill & downhill walking was found to be significant. The step time is only a good indicator to see if a person is walking uphill compared to downhill.

Parameter 2: time difference between the beginning and the maximum force and the posterior phase. The difference between uphill & downhill and uphill & level walking were found to be significant. This parameter could be a good indicator to see if a person is walking uphill.

Parameter 3: the time difference between the maximum force of the posterior phase and the intersection. The difference between uphill & downhill and uphill & level walking were found to be significant. This parameter could be a good indicator to see if a person is walking downhill.

Parameter 4: time difference between the intersection and the maximum force of the anterior phase. The difference between uphill & downhill and downhill & level walking were found to be significant. This parameter could be a good indicator to see if a person is walking downhill

Parameter 5: ratio between the heights of the peaks. No significant difference was found. This parameter cannot be used as an indicator.

Parameter 6: ratio between the weight of the anterior and the posterior phase. The difference between uphill & downhill and uphill & level walking were found to be significant. This parameter could be a good indicator to see if a person is walking downhill.

Reference list

Broeren, B. (2017, february 2). Construeren II, Buiging mechanica sterkteleer. 76-77.

El-Rabbany, A. (2002). Introduction to GPS. In A. El-Rabbany, *Introduction to GPS, The Blobal Positioning System* (pp. 1-11). Boston, Engeland: Artech House, INC.

European Union. (2016). *Projects*. Retrieved 03 05, 2017, from Interreg V-A Italien – Österreich: http://www.interreg.net/en/projects.asp

Grampp, J., Willson, J., & Kernozek, T. (2000, march). The Plantar Loading Variations to Uphill and Downhill Gradiens During Treadmill Walking. *Foot & Ankle International*(3), 227-231.

Item, HABERKORN. (2017). *Profil 8 40x40 leicht, natur*. Retrieved from Item, HABERKORN: http://product.item24.at/home/produkte/produktkatalog/produktdetails/products/konstruktionsprofile-8/profil-8-40x40-leicht-natur-2633.html

Keller, T. S., Weisberger, A. M., Ray, J. L., Hasan, S. S., Shiavi, R. G., & Spengler, D. M. (1995, october 13). Relationship between vertical ground reaction force and speed during walking, slow jogging, and running. *Clinical Eiomerhanics, 11*(5), 253-259.

Koch, M., Lunde, L.-K., Ernst, M., Knardahl, S., & Veiersted, K. B. (2016). Validity and reliability of the pressure-measurement insoles for vertical ground reaction force assessment in field situation. *Applied Ergonomics*(53), 44-51.

Ministerie van Sociale zaken en Werkgelegenheid. (2010). *Tillen en dragen*. Retrieved 04 15, 2017, from arboportaal: https://www.arboportaal.nl/onderwerpen/tillen-en-dragen/vraag-en-antwoord/hoeveel-mag-een-werknemer-tillen

Price, C., Parker, D., & Nester, C. (2016, january 27). Validity and repeatability of three in-shoe pressure measurement systems. *Gait & Posture*(46), 69-74.

Tiroler Landesregierung. (2011). *Streckennetz*. Retrieved from Tirol, Unser Land: https://www.tirol.gv.at/sport/richtlinien-initiativen/laufen/streckennetz/

TU Delft. (2004). *Dutch adults, dined2004.* Retrieved from DINED, Anthropometric database: http://dined.io.tudelft.nl/en/database/tool

Twombly, S. E., & Schussman, L. C. (1995). Gender differences in injury and illness rates on wilderness backpacking trips. Wilderness. *Environ Med* (4), 363–376.

Wannop, J. W., Worobets, J. T., Ruiz, R., & Darren, S. J. (2014, march 3). Footwear traction and three-dimensional kinematics of level, downhill, uphill and cross-slope walking. *Gait & Posture*(40), 118-122.

Yung-Hui, L., & Wei-Hsien, H. (2004, november 12). Effects of shoe inserts and heel height on foot pressure, impact force, and perceived comfort during walking. *Applied Ergonomics*(36), 355–362.

Appendix

A1

Information letter validation study

Date: 27 March 2017
Place: Pulverturm, Fürstenweg 187, IBK

Dear …,
At first, we really want to thank you for your participation in our study. In this letter, there will be given information about the measurements we are going to do and what we expect from you. In total the measurement will take about 30 minutes.
The main goal of this study is to see if the Medilogic insoles are valid to the Kistler force plate. Therefore, two different measurements will be done in which you are participating.

1. In the first measurement, we want to see how the pressure insoles behave with statistic poses. Therefore, you need to be able to stand on your toes, heels, inner- and outer foot. This will be done on the force plate. During the measurement, you are wearing the Medilogic insoles and shoes from us. We will give a detailed briefing how you have to do this and there is time calculated to practise the poses
   This measurement will take about 15 minutes.
2. In the second measurement, we want to see how the pressure insoles behave with a dynamic walking pattern. Therefore, you need to walk 5 times over the Kistler force plate. During the gait you are wearing the Medilogic insoles and shoes from us. We will give a detailed briefing how you have to do this and there is time calculated to practise the walking
   This measurement will also take about 15minutes.

Make sure you bring **socks**. The rest of the outfit does not really matter.

We will see you on …th april.
cheers,

Babette van Hout and Welmoed Sinnema
Bachlor students Human Kinetic Technology

A2

Information subjects

Table A1: Information subjects

Subject	Name	Gender	Age in years	Weight in Kg	Shoe size EU
1	Armin Niederkofler	M	45	70	43/44
2	Babette van Hout	F	22	62	39/40
3	Christoph Hasler	M	38	78	43/44
4	Daniel Sedláček	M	25	72	43/44
5	Joost van Putten	M	29	83	43/44
6	Maria Schwartz	F	23	56	39/40
7	Simona Hops	F	26	68	39/40
8	Sebastian Rohm	M	35	84	43/44
9	Michèle Erpelding	F	22	65	39/40
10	Welmoed Sinnema	F	22	81	39/40

A3

Visual programming with LabVIEW

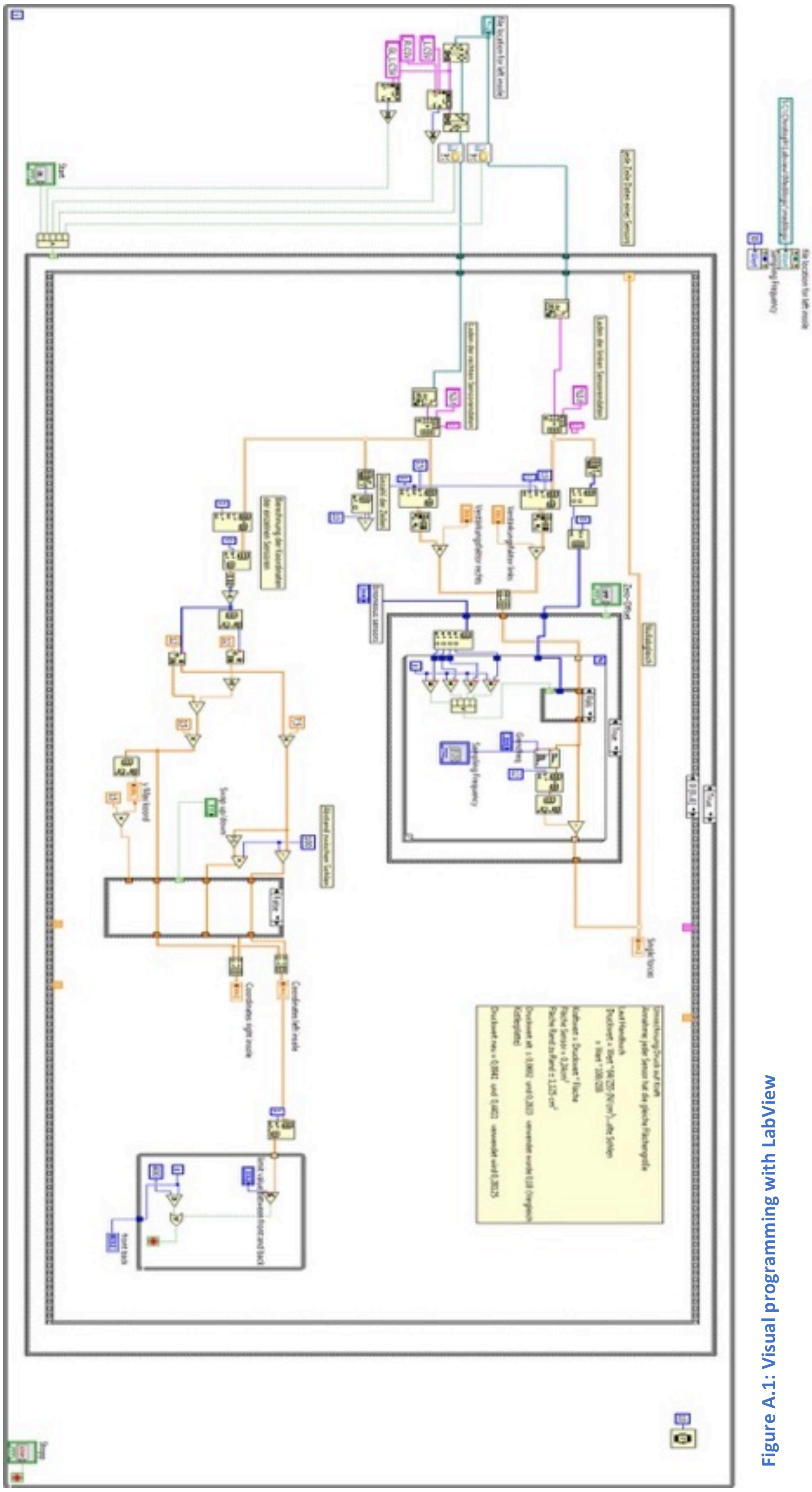


Figure A.1: Visual programming with LabView

A4

MATLAB script for the static measurement with subjects.

```
clear all
close all
%% inladen data kistler
disp('laad linker kistler data in')
% bestand kiezen
filenaam = uigetfile('.xlsx');
% xlsread(naam, sheet, kolommen)
% sheet 1 dartfish tagging data
% Kolom C=tijd D=Actie E=outcome F=toebehoren
%Benoemen van de markerpunten uit het xlsx bestand
kistL = xlsread(filenaam);
%% gemiddelde berekenen kistler

PiekKistlerL= max(kistL(:,3));
framenummerKistlerLPiek=find(kistL(:,3)==PiekKistlerL
);
startKL= (framenummerKistlerLPiek+90);
eindKL=(framenummerKistlerLPiek+150);

GemSigKistL= mean(kistL(startKL:eindKL,3))
%% plotten
KistlerLsignaal=kistL(:,3);

n = length(kistL);
dt=1/30;
k = 0:n-1;
t1= k*dt;

figure(1)
plot (t1,KistlerLsignaal)
title('Signal Kistler left');
xlabel('Time [s]')
ylabel('Force [N]');
%% inladen data kistler
disp('laad rechter kistler data in')
% bestand kiezen
filenaam = uigetfile('.xlsx');
% xlsread(naam, sheet, kolommen)
% Kolom C=tijd D=Actie E=outcome F=toebehoren
%Benoemen van de markerpunten uit het xlsx bestand
kistR = xlsread(filenaam);
%% gemiddelde berekenen kistler

PiekKistlerR= max(kistR(:,3));
framenummerKistlerRPiek=find(kistR(:,3)==PiekKistlerR
);
startKR= (framenummerKistlerRPiek+90);
eindKR=(framenummerKistlerRPiek+130);

GemSigKistR= mean(kistR(startKR:eindKR,3))
%% plotten
KistlerRsignaal=kistR(:,3);

n = length(kistR);
dt=1/30;
k = 0:n-1;
t2= k*dt;

figure(2)
plot (t2,KistlerRsignaal)
title('Signal kistler right');
xlabel('Time [s]')
ylabel('Force [N]');

%% data inladen medilogic
disp('laad linker medilogic data in')
% bestand kiezen
filenaam = uigetfile('.xlsx');
% xlsread(naam, sheet, kolommen)
% Kolom 1=tijd, kolom 2=totaal kracht, kolom 3=tijd
links, kolom 4=kracht links, kolom 5=tijd rechts,
kolom 6=kracht rechts
%Benoemen van de markerpunten uit het xlsx bestand
medL = xlsread(filenaam);
%% gemiddelde berekenen medilogic linker been
PiekMedL = max(medL(:,4));
framenummerMedLPiek=find(medL(:,4)==PiekMedL);
startML= (framenummerMedLPiek+90);
eindML=(framenummerMedLPiek+150);

GemsigMedL= mean(medL(startML:eindML,4))
medilogicLsignaal=medL(:,4);
n = length(medL);
dt=1/30;
k = 0:n-1;
t3= k*dt;

figure(3)
plot (t3,medilogicLsignaal)
title('Signal Medilogic left');
xlabel('Time [s]')
ylabel('Force [N]');
%% data inladen medilogic
disp('laad rechter medilogic data in')
% bestand kiezen
filenaam = uigetfile('.xlsx');
% xlsread(naam, sheet, kolommen)
% Kolom 1=tijd, kolom 2=totaal kracht, kolom 3=tijd
links, kolom 4=kracht links, kolom 5=tijd rechts,
kolom 6=kracht rechts

%Benoemen van de markerpunten uit het xlsx bestand
medR = xlsread(filenaam);

%% gemiddelde berekenen medilogic rechter been
PiekMedR = max(medR(:,6));
framenummerMedRPiek=find(medR(:,6)==PiekMedR);
startMR= (framenummerMedRPiek+90);
eindMR=(framenummerMedRPiek+150);

GemsigMedR= mean(medR(startMR:eindMR,6))
medilogicRsignaal=medR(:,6);

n = length(medR);
dt=1/30;
k = 0:n-1;
t4= k*dt;

figure(4)
plot (t4,medilogicRsignaal)
title('Signal Medilogic right');
xlabel('Time [s]')
ylabel('Force [N]');

%%
SignaalGemK=kistL(startKL:eindKL,3);
n = length(startKL:eindKL);
dt=1/30;
k = 0:n-1;
t5= k*dt;

figure(5)
plot (t5,SignaalGemK)
title('Average signal Kistler left');
xlabel('Time [s]')
ylabel('Force [N]');

SignaalGemK=kistR(startKR:eindKR,3);
n = length(startKR:eindKR);
dt=1/30;
k = 0:n-1;
t6= k*dt;

figure(6)
plot (t6,SignaalGemK)
title('Average signal Kistler right');
xlabel('Time [s]')
ylabel('Force [N]');

SignaalGemML=medL(startML:eindML,4);
n = length(startML:eindML);
dt=1/30;
k = 0:n-1;
t7= k*dt;

figure(7)
plot (t7,SignaalGemML)
title('Average signal Medilogic left');
xlabel('Time [s]')
ylabel('Force [N]');

SignaalGemMR=medR(startMR:eindMR,6);
n = length(startMR:eindMR);
dt=1/30;
k = 0:n-1;
t8= k*dt;

figure(8)
plot (t8,SignaalGemMR)
title('Average signal Medilogic right');
xlabel('Time [s]')
ylabel('Force [N]');
```

A5

Certificate of Calibration

medilogic

T&T medilogic Medizintechnik GmbH
Mittelstraße 9, D-12529 Schönefeld

KALIBRIERZERTIFIKAT

Auftraggeber: Universität Innsbruck
Institut für Sportwissenschaft Technologiezentrum Ski- und Alpinsport GmbH

, A-6020 Innsbruck

Auftrag Nr.: 3370-20

Verwendete Kalibriereinrichtung: Druckluft -Kalibrierkammer: Computergestützte polybare Kennlinienaufnahme, max. Messfehler ± 0,575 N/cm²

Rückführung auf die Nationalen Normale:
- Drucksensor: SensorTechnica 142SC100D-PCB, Ser.Nr. 500201; Kal.-Datum: 30.01.2015
- AD-Wandler: T&T medilogic; Ser.Nr. P11-501076; Zertifikat-Nr. 130412; Kal.-Datum: 30.01.2015

Die Kalibrierung der nachfolgend aufgeführten Drucksensoren der Firma T&T medilogic Medizintechnik GmbH wurde entsprechend den firmeninternen V (Dokument 101.05) im Rahmen des zertifizierten Qualitätsmanagementsystems

Kalibrierdatum:	19.01.2017
Empf. Zyklus:	12 Monate
Kalibriergegenstand:	Seriennummer:
SohleFlex 33 li	137_722013
SohleFlex 33 re	137_722113
SohleFlex 35 li	137_722213
SohleFlex 35 re	137_722313
SohleFlex 37 li	137_722413
SohleFlex 37 re	137_722513
SohleFlex 39 li	137_722613
SohleFlex 39 re	137_722713
SohleFlex 41 li	137_722813
SohleFlex 41 re	137_722913

Schönefeld, 19.01.2017

T & T medilogic Medizintechnik GmbH

i.A.

Dr.-Ing. Heiko Tober

medilogic

T&T medilogic Medizintechnik GmbH
Mittelstraße 9, D-12529 Schönefeld

REPARATURBERICHT

16.12.2016

Reparaturauftrag Nr.:3370-20
Universität Innsbruck
Institut für Sportwissenschaft Technologiezentrum Ski- und Alpinsport GmbH

, A-6020 Innsbruck

Sehr geehrter Kunde,
wir haben an Ihrem System folgendes festgestellt und geleistet:

Komponente	SerienNr.	Analyse	Maßnahme
Upat4 medilogic	502612087U	Gehäuse gebrochen	Gehäuse ersetzt
Empfänger U4 medilogic	502612087E	Funkmod OK	Funktion geprüft
SohleFlex 33 li	137_722013	Sohle ok	kalibriert
SohleFlex 33 re	137_722113	Sohle ok	kalibriert
SohleFlex 35 li	137_722213	Zeilen-/Spaltenausfall	Sensorik ersetzt, kalibriert
SohleFlex 35 re	137_722313	Zeilen-/Spaltenausfall	Sensorik ersetzt, kalibriert
SohleFlex 37 li	137_722413	Zeilen-/Spaltenausfall	Sensorik ersetzt, kalibriert
SohleFlex 37 re	137_722513	Zeilen-/Spaltenausfall	Sensorik ersetzt, kalibriert
SohleFlex 39 li	137_722613	Sohle ok	kalibriert
SohleFlex 39 re	137_722713	Sohle ok	kalibriert
SohleFlex 41 li	137_722813	Zeilen-/Spaltenausfall	Sensorik ersetzt, kalibriert
SohleFlex 41 re	137_722913	Zeilen-/Spaltenausfall	Sensorik ersetzt, kalibriert

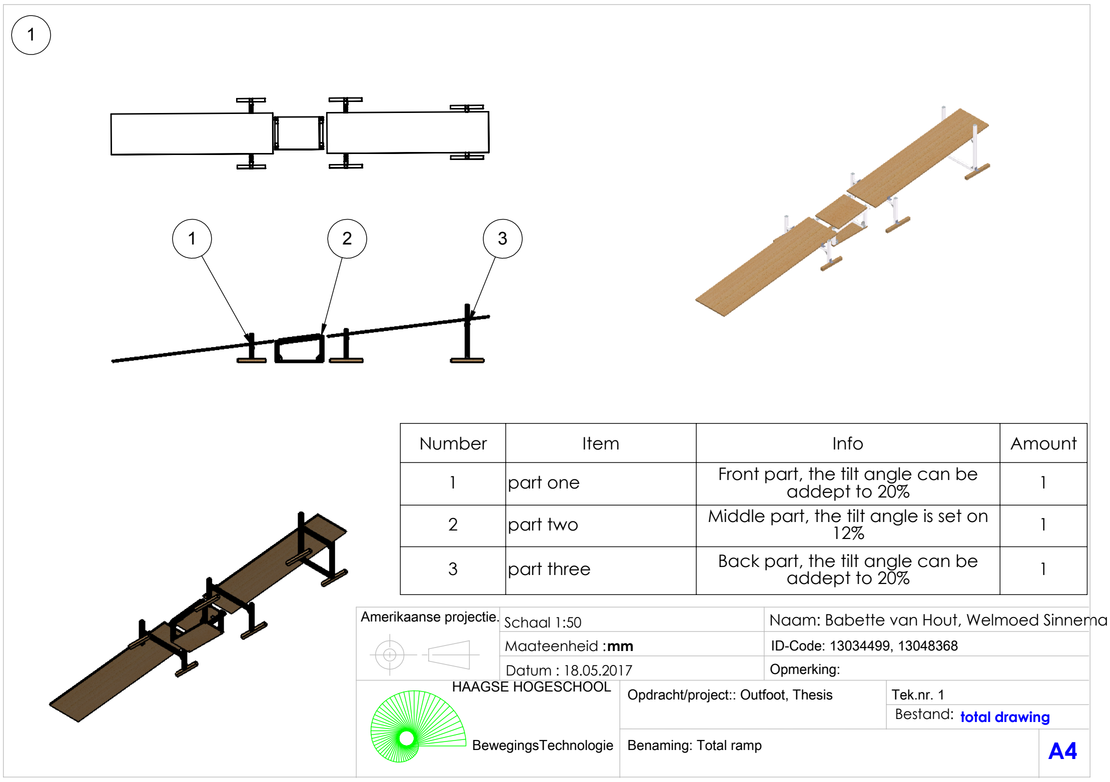
Mit freundlichen Grüßen
Ihr T&T medilogic Team

(Kirste)

Figure A.2: Certificate of calibration

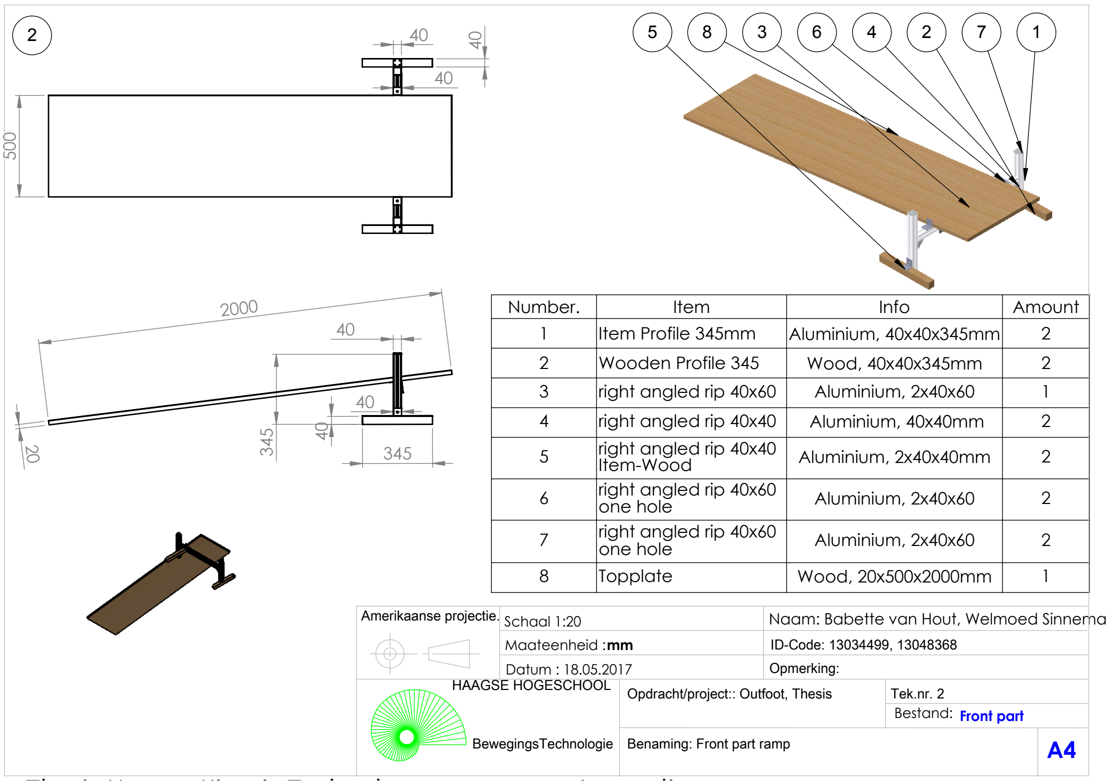
A6

Blueprints of the ramp



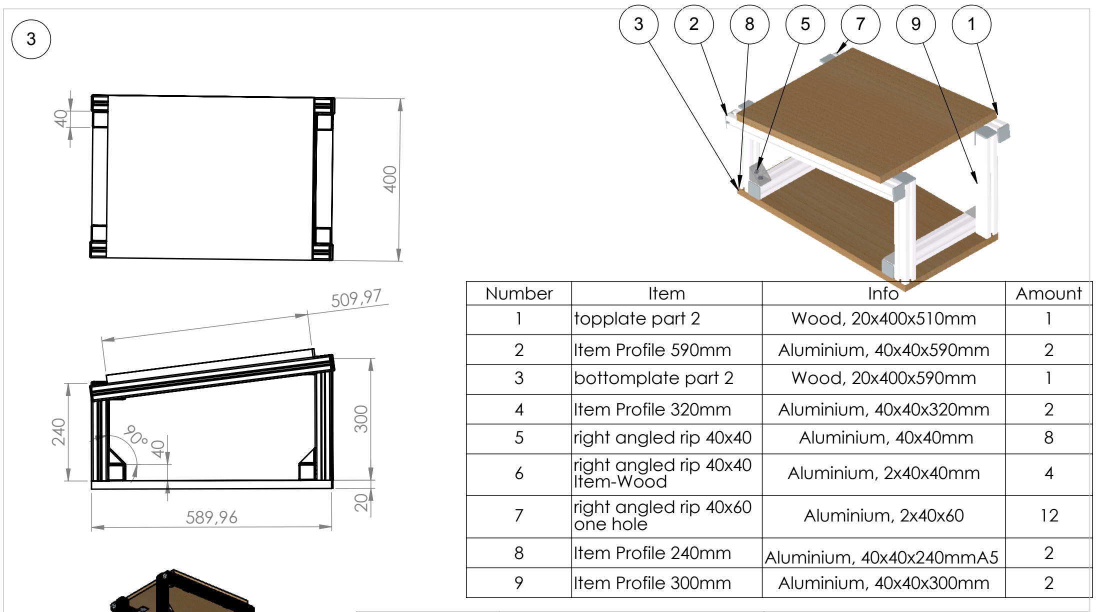
Number	Item	Info	Amount
1	part one	Front part, the tilt angle can be addept to 20%	1
2	part two	Middle part, the tilt angle is set on 12%	1
3	part three	Back part, the tilt angle can be addept to 20%	1

Figure A.3: Blueprint, total construction



Number.	Item	Info	Amount
1	Item Profile 345mm	Aluminium, 40x40x345mm	2
2	Wooden Profile 345	Wood, 40x40x345mm	2
3	right angled rip 40x60	Aluminium, 2x40x60	1
4	right angled rip 40x40	Aluminium, 40x40mm	2
5	right angled rip 40x40 Item-Wood	Aluminium, 2x40x40mm	2
6	right angled rip 40x60 one hole	Aluminium, 2x40x60	2
7	right angled rip 40x60 one hole	Aluminium, 2x40x60	2
8	Topplate	Wood, 20x500x2000mm	1

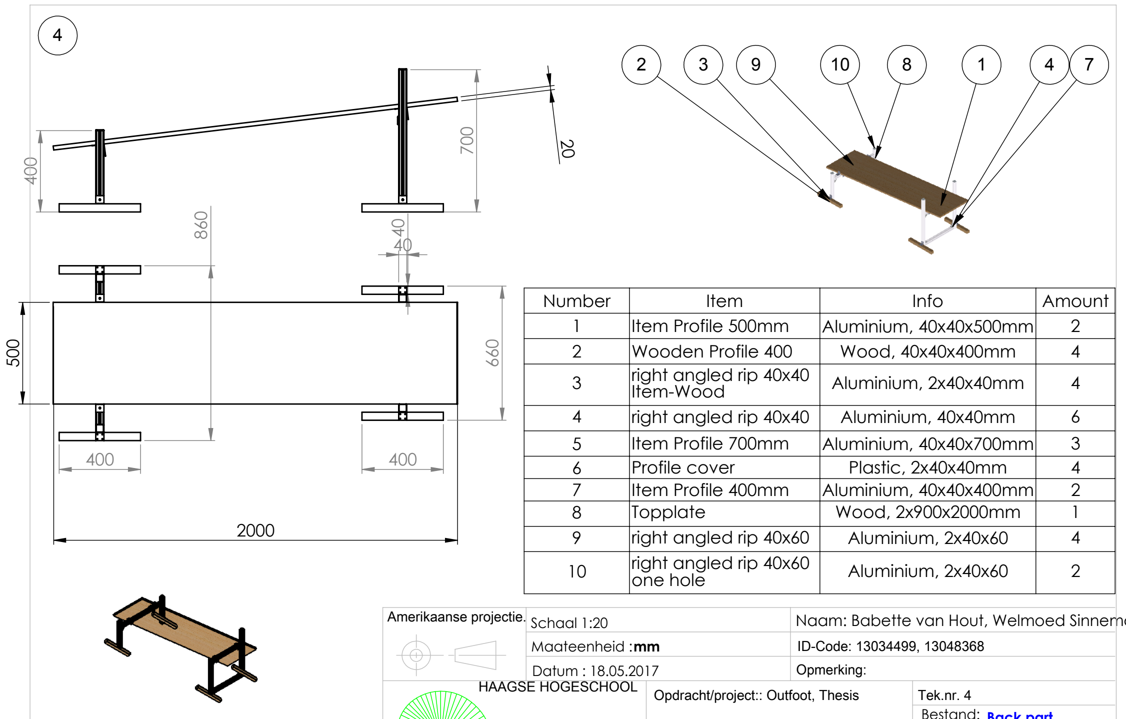
Figure A.4: Blueprint lower part



Number	Item	Info	Amount
1	topplate part 2	Wood, 20x400x510mm	1
2	Item Profile 590mm	Aluminium, 40x40x590mm	2
3	bottomplate part 2	Wood, 20x400x590mm	1
4	Item Profile 320mm	Aluminium, 40x40x320mm	2
5	right angled rip 40x40	Aluminium, 40x40mm	8
6	right angled rip 40x40 Item-Wood	Aluminium, 2x40x40mm	4
7	right angled rip 40x60 one hole	Aluminium, 2x40x60	12
8	Item Profile 240mm	Aluminium, 40x40x240mmA5	2
9	Item Profile 300mm	Aluminium, 40x40x300mm	2

Amerikaanse projectie. Schaal 1:10 | Naam: Babette van Hout, Welmoed Sinnema
Maateenheid :**mm** | ID-Code: 13034499, 13048368
Datum : 18.05.2017 | Opmerking:
HAAGSE HOGESCHOOL | Opdracht/project:: Outfoot, Thesis | Tek.nr. 3
Bestand: **Middle part**
BewegingsTechnologie | Benaming: Middle part ramp | **A4**

Figure A.4: Blueprint lower part



Number	Item	Info	Amount
1	Item Profile 500mm	Aluminium, 40x40x500mm	2
2	Wooden Profile 400	Wood, 40x40x400mm	4
3	right angled rip 40x40 Item-Wood	Aluminium, 2x40x40mm	4
4	right angled rip 40x40	Aluminium, 40x40mm	6
5	Item Profile 700mm	Aluminium, 40x40x700mm	3
6	Profile cover	Plastic, 2x40x40mm	4
7	Item Profile 400mm	Aluminium, 40x40x400mm	2
8	Topplate	Wood, 2x900x2000mm	1
9	right angled rip 40x60	Aluminium, 2x40x60	4
10	right angled rip 40x60 one hole	Aluminium, 2x40x60	2

Amerikaanse projectie. Schaal 1:20 | Naam: Babette van Hout, Welmoed Sinnema
Maateenheid :**mm** | ID-Code: 13034499, 13048368
Datum : 18.05.2017 | Opmerking:
HAAGSE HOGESCHOOL | Opdracht/project:: Outfoot, Thesis | Tek.nr. 4
Bestand: **Back part**
BewegingsTechnologie | Benaming: Back part ramp | **A4**

Figure A.6: Blueprint higher part

A7

Total construction

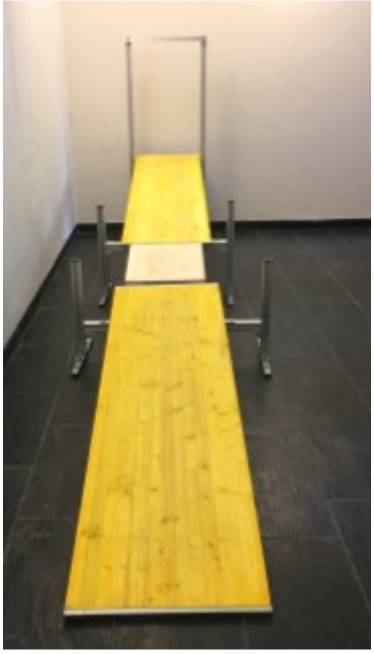


Figure A.7: Physical model, total construction

Lower part

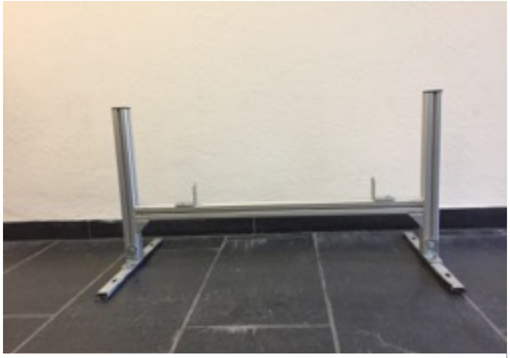


Figure A.8: Lower part, support system front view

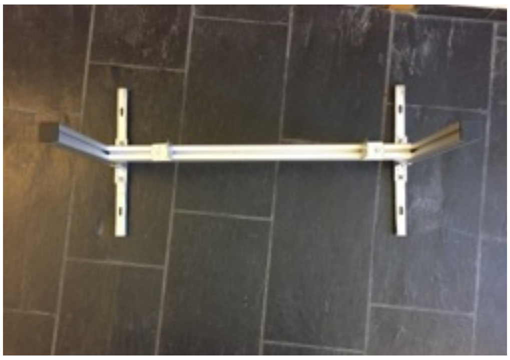


Figure A.9: Lower part, support system top view

Figure A.10: Lower part, support system bottom view

Figure A.11: Lower part, wooden plates, bottom and top view

Middle part

Figure A.12: Middle part, side vieuw

Figure A.13: Middle part, front view

Figure A.14: Middle part inside view

Figure A.15: Middle part, bottom view

Higher part

Figure A.16: Support system 1 of the higher part, front view

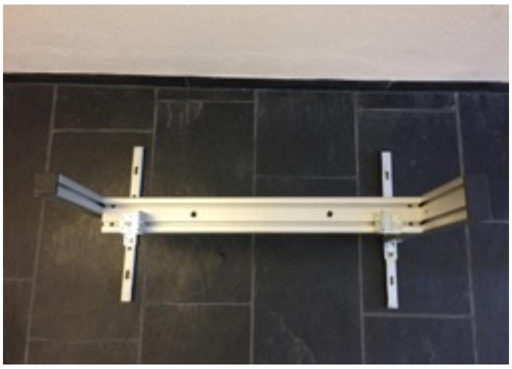


Figure A.17: Support system 1 of the higher part, top view

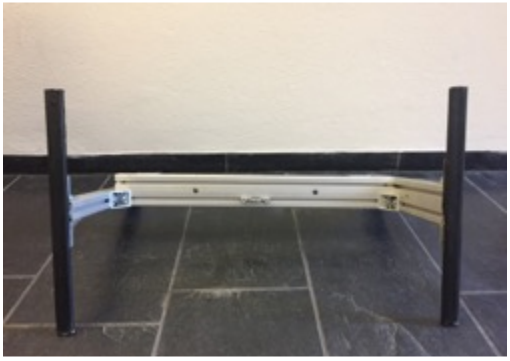


Figure A.18: Support system 1 of the higher part, bottom view

Figure A.19: Support system 2 of the higher part, bottom view

Figure A.20: Support system 2 of the higher part, top view

Figure A.21: Support system 2 of the higher part, front vie

Figure A.22: Wooden plates higher part, top and bottom view

A8

Information letter OutFeet

Date: 19 May 2017
Place: Pulverturm, Fürstenweg 187, IBK

Dear …,
At first, we really want to thank you for your participation in our study. In this letter, there will be given information about the measurements we are going to do and what we expect from you. In total the measurement will take about 30 minutes.
The main goal of this study is to see if there are changes in parameters when uphill and downhill walking compared to level walking. Therefore, two measurements will be done on a ramp and one measurement will be done on the floor surface.

1. In the first measurement, you are going to walk up the ramp. During the measurement you will wear the Medilogic insoles. You have to walk up for five times. Before we are going to measure there will be a detailed briefing how you have to do this and there is time calculated to practise the walking.
   This measurement will take about 10 minutes.
2. For the second measurement you have to walk 5 times down the ramp. There will be a briefing and some practise time as well.
   This measurement will take about 10 minutes.
3. For the last measurement you have to walk over the force plate itself for five times. For this measurement there will be again a briefing and some practise time.
   This measurement will take about 10 minutes.

Make sure you bring **socks, tight leggings/sport pans**, and a **tight t-shirt**. Be aware that details about the tests cannot be discussed with other subjects.

We will see you on ...th may!
Cheers,

Babette van Hout and Welmoed Sinnema
Bachelor students Human Kinetic Technology

Table 1: Time table

Time	24.05.2017	26.05.2017
9-9^{30}	Christophe Hasler	Armin Niederkofler
9^{35}-10^{05}	Maria Schwartz	Babette van Hout
10^{10}-10^{40}	Corina Wolf	Welmoed Sinnema
10^{45}-11^{15}	Sebastian Rohm	Michèle Erpelding
11^{20}-11^{50}	Daniel Sedláček	
11^{55}-12^{25}	Joost van Putten	
12^{30}-13^{00}		

A9

MATLAB script for the measurement on the ramp

```
clear all
close all

%% data omhoog inladen medilogic

disp('laad rechter medilogic omhoog in')
% bestand kiezen
filenaam = uigetfile('.xlsx');
% xlsread(naam, sheet, kolommen)
% Kolom 1=tijd, kolom 2=totaal kracht, kolom 3=tijd anterior, kolom
% 4=kracht anterior, kolom 5=tijd posterior, kolom 6=kracht posterior

% Benoemen van de markerpunten uit het xlsx bestand
medRHoog = xlsread(filenaam);

n = length(medRHoog);
dt=1/30;
k = 0:n-1;
t= k*dt;
%% waardes merkpunten.
%begin posterior om offset eraf te trekken
plot (t,medRHoog(:,6))
title ('Posterion distribution')
legend ('Posterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt posterior aan')
[xphb yphb] = ginput(1)

%begin posterior om offset eraf te trekken
plot (t,medRHoog(:,4))
title ('Anterior distribution')
legend ('anterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt Anterior aan')
[xahb yahb] = ginput(1)
%offset aftekken van signaal
medRHoog(:,4)=medRHoog(:,4)-yahb;
medRHoog(:,6)=medRHoog(:,6)-yphb;

%X en Y waardes startpunt posterior en het eindpunt posterior
plot (t,medRHoog(:,6))
title ('Posterion distribution')
legend ('Posterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt posterior aan, daarna het eindpunt posterior')
[xphb yphb] = ginput(1)
[xphe yphe] = ginput(1)
%X en Y waardes startpunt posterior en het eindpunt posterior
plot (t,medRHoog(:,4))
title ('Anterior distribution')
legend ('anterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt Anterior aan, vervolgens het eindpunt anterior')
[xahb yahb] = ginput(1)
[xahe yahe] = ginput(1)

%X en Y waardes intersection
plot (t,medRHoog(:,6), t,medRHoog(:,4))
title ('max till intersection')
legend ('Posterior', 'anterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik het kruispunt aan')
[xih yih] = ginput(1)

%% berekenen ratio voor en achter
[MaxAnteriorH WaardemaxAH]=max(medRHoog(:,4));
[MaxPosteriorH WaardemaxPH]=max(medRHoog(1:30,6));
```

```
RatioHoog=(MaxAnteriorH/MaxPosteriorH);
WaardemaxAH=WaardemaxAH*dt
WaardemaxPH=WaardemaxPH*dt
%% bereken time difference tussen pieken
TimestartH = find(medRHoog(1:30,6) == MaxPosteriorH);
if max(size(TimestartH)) > 1
  TimestartH = TimestartH(1:1);
end
TimeendH = find(medRHoog(:,4) == MaxAnteriorH);
if max(size(TimeendH)) > 1
  TimeendH = TimeendH(1:1);
end

TimestartH=TimestartH*dt;
TimeendH=TimeendH*dt;

DifferenceH=(TimeendH-TimestartH);

%% tijd van startpunt tot max posterior
timeMaxPosteriorH= find (medRHoog(:,6) == MaxPosteriorH);
if max(size(timeMaxPosteriorH))>1
  timeMaxPosteriorH=timeMaxPosteriorH(1:1);
end
TimetoMaxPH= (timeMaxPosteriorH*dt)-(xphb);
%% tijd van max posterior intersection
timeMaxPosteriorH= find (medRHoog(:,6) == MaxPosteriorH);
if max(size(timeMaxPosteriorH))>1
  timeMaxPosteriorH=timeMaxPosteriorH(1:1);
end
TimeMaxtoIntPH= (xih)-(timeMaxPosteriorH*dt);

%% intersection tot eind posterior
TimeInttoendPH=(xphe)-(xih);

%% tijd van startpunt tot intersection anterior
TimestarttoIntAH= (xih)-(xahb);

%% Tijd intersection tot max anterior
timeMaxAnteriorH= find (medRHoog(:,4) == MaxAnteriorH);
if max(size(timeMaxAnteriorH))>1
  timeMaxAnteriorH=timeMaxAnteriorH(1:1);
end
TimeInttomaxAH= (timeMaxAnteriorH*dt)-(xih);

%% tijd van max anterior tot eind
timeMaxAnteriorH= find (medRHoog(:,4) == MaxAnteriorH);
if max(size(timeMaxAnteriorH))>1
  timeMaxAnteriorH=timeMaxAnteriorH(1:1);
end
TimefromMaxAH= (xahe)-(timeMaxAnteriorH*dt);
%% Totale staptijd
TotalStepH= (xahe-xphb)

%% ratio breedte grafieken
RatiobreedteH =(TimetoMaxPH+TimeMaxtoIntPH)/(TimeInttomaxAH+TimefromMaxAH)

%% data omlaag inladen
disp('laad rechter medilogic omlaag in')
% bestand kiezen
filenaam = uigetfile('.xlsx');
% xlsread(naam, sheet, kolommen)
% Kolom 1=tijd, kolom 2=totaal kracht, kolom 3=tijd anterior, kolom
% 4=kracht anterior, kolom 5=tijd posterior, kolom 6=kracht posterior

%Benoemen van de markerpunten uit het xlsx bestand
medRlaag = xlsread(filenaam);

%% waardes merkpunten
%begin posterior om offset eraf te trekken
plot (t,medRlaag(:,6))
title ('Posterion distribution')
legend ('Posterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt posterior aan')
[xplb yplb] = ginput(1)
```

```
%begin posterior om offset eraf te trekken
plot (t,medRlaag(:,4))
title ('Anterior distribution')
legend ('anterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt Anterior aan')
[xalb yalb] = ginput(1)
%offset aftekken van signaal
medRlaag(:,4)=medRlaag(:,4)-yalb;
medRlaag(:,6)=medRlaag(:,6)-yplb;

%X en Y waardes startpunt posterior en het eindpunt posterior
plot (t,medRlaag(:,6))
title ('Posterion distribution')
legend ('Posterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt posterior aan, daarna het eindpunt posterior')
[xplb yplb] = ginput(1)
[xple yple] = ginput(1)
%X en Y waardes startpunt posterior en het eindpunt posterior
plot (t,medRlaag(:,4))
title ('Anterior distribution')
legend ('anterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt Anterior aan, vervolgens het eindpunt anterior')
[xalb yalb] = ginput(1)
[xale yale] = ginput(1)

%X en Y waardes intersection
plot (t,medRlaag(:,6), t,medRlaag(:,4))
title ('max till intersection')
legend ('Posterior', 'anterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik het kruispunt aan')
[xil yil] = ginput(1)
%% berekenen ratio voor en achter
[MaxAnteriorL WaardemaxAL]=max(medRlaag(:,4));
[MaxPosteriorL WaardemaxPL]=max(medRlaag(1:30,6));

RatioLaag=(MaxAnteriorL/MaxPosteriorL);
WaardemaxAL=WaardemaxAL*dt
WaardemaxPL=WaardemaxPL*dt
%% bereken time difference tussen pieken
TimestartL = find(medRlaag(1:30,6) == MaxPosteriorL);
if max(size(TimestartL)) > 1
  TimestartL = TimestartL(1:1);
end
TimeendL = find(medRlaag(:,4) == MaxAnteriorL);
if max(size(TimeendL)) > 1
  TimeendL = TimeendL(1:1);
end

TimestartL=TimestartL*dt;
TimeendL=TimeendL*dt;

DifferenceL=(TimeendL-TimestartL);

%% tijd van startpunt tot max posterior
timeMaxPosteriorL= find (medRlaag(:,6) == MaxPosteriorL);
if max(size(timeMaxPosteriorL))>1
  timeMaxPosteriorL=timeMaxPosteriorL(1:1);
end
TimetoMaxPL= (timeMaxPosteriorL*dt)-(xplb);
%% tijd van max posterior intersection
timeMaxPosteriorL= find (medRlaag(:,6) == MaxPosteriorL);
if max(size(timeMaxPosteriorL))>1
  timeMaxPosteriorL=timeMaxPosteriorL(1:1);
end
TimeMaxtoIntPL= (xil)-(timeMaxPosteriorL*dt);

%% intersection tot eind posterior
TimeInttoendPL=(xple)-(xil);

%% tijd van startpunt tot intersection anterior
TimestarttoIntAL= (xil)-(xalb);
```

```
%% Tijd intersection tot max anterior
timeMaxAnteriorL= find (medRlaag(:,4) == MaxAnteriorL);
if max(size(timeMaxAnteriorL))>1
  timeMaxAnteriorL=timeMaxAnteriorL(1:1);
end
TimeInttomaxAL= (timeMaxAnteriorL*dt)-(xil);

%% tijd van max anterior tot eind
timeMaxAnteriorL= find (medRlaag(:,4) == MaxAnteriorL);
if max(size(timeMaxAnteriorL))>1
  timeMaxAnteriorL=timeMaxAnteriorL(1:1);
end
TimefromMaxAL= (xale)-(timeMaxAnteriorL*dt);
%% Totale staptijd
TotalStepL= (xale-xplb)
%% ratio breedte grafieken
RatiobreedteL =(TimetoMaxPL+TimeMaxtoIntPL)/(TimeInttomaxAL+TimefromMaxAL)
%% data level inladen
disp('laad rechter medilogic level in')
%bestand kiezen
filenaam = uigetfile('.xlsx');
%xlsread(naam, sheet, kolommen)
%Kolom 1=tijd, kolom 2=totaal kracht, kolom 3=tijd anterior, kolom
%4=kracht anterior, kolom 5=tijd posterior, kolom 6=kracht posterior
%Benoemen van de markerpunten uit het xlsx bestand
medRlevel = xlsread(filenaam);
%begin posterior om offset eraf te trekken
plot (t,medRlevel(:,6))
title ('Posterion distribution')
legend ('Posterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt posterior aan')
[xpnb ypnb] = ginput(1)
%begin posterior om offset eraf te trekken
plot (t,medRlevel(:,4))
title ('Anterior distribution')
legend ('anterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt Anterior aan')
[xanb yanb] = ginput(1)
%offset aftekken van signaal
medRlevel(:,4)=medRlevel(:,4)-yanb;
medRlevel(:,6)=medRlevel(:,6)-ypnb;
%X en Y waardes startpunt posterior en het eindpunt posterior
plot (t,medRlevel(:,6))
title ('Posterion distribution')
legend ('Posterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt posterior aan, daarna het eindpunt posterior')
[xpnb ypnb] = ginput(1)
[xpne ypne] = ginput(1)
%X en Y waardes startpunt posterior en het eindpunt posterior
plot (t,medRlevel(:,4))
title ('Anterior distribution')
legend ('anterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik startpunt Anterior aan, vervolgens het eindpunt anterior')
[xanb yanb] = ginput(1)
[xane yane] = ginput(1)
%X en Y waardes intersection
plot (t,medRlevel(:,6), t,medRlevel(:,4))
title ('max till intersection')
legend ('Posterior', 'anterior')
xlabel ('Time (s)')
ylabel ('Force (N)')
disp ('klik het kruispunt aan')
[xin yin] = ginput(1)
%% berekenen ratio voor en achter
[MaxAnteriorN WaardemaxAN]=max(medRlevel(:,4));
[MaxPosteriorN WaardemaxPN]=max(medRlevel(1:30,6));

RatioLevel=(MaxAnteriorN/MaxPosteriorN);
WaardemaxAN=WaardemaxAN*dt
WaardemaxPN=WaardemaxPN*dt
%% bereken time difference tussen pieken
TimestartN = find(medRlevel(1:30,6) == MaxPosteriorN);
```

```
if max(size(TimestartN)) > 1
  TimestartN = TimestartN(1:1);
end
TimeendN = find(medRlevel(:,4) == MaxAnteriorN);
if max(size(TimeendN)) > 1
  TimeendN = TimeendN(1:1);
end
TimestartN=TimestartN*dt;
TimeendN=TimeendN*dt;
DifferenceN=(TimeendN-TimestartN);
%% tijd van startpunt tot max posterior
timeMaxPosteriorN= find (medRlevel(:,6) == MaxPosteriorN);
if max(size(timeMaxPosteriorN))>1
  timeMaxPosteriorN=timeMaxPosteriorN(1:1);
end
TimetoMaxPN= (timeMaxPosteriorN*dt)-(xpnb);
%% tijd van max posterior intersection
timeMaxPosteriorN= find (medRlevel(:,6) == MaxPosteriorN);
if max(size(timeMaxPosteriorN))>1
  timeMaxPosteriorN=timeMaxPosteriorN(1:1);
end
TimeMaxtoIntPN= (xin)-(timeMaxPosteriorN*dt);
%% intersection tot eind posterior
TimeInttoendPN=(xpne)-(xin);

%% tijd van startpunt tot intersection anterior
TimestarttoIntAN= (xin)-(xanb);

%% Tijd intersection tot max anterior
timeMaxAnteriorN= find (medRlevel(:,4) == MaxAnteriorN);
if max(size(timeMaxAnteriorN))>1
  timeMaxAnteriorN=timeMaxAnteriorN(1:1);
end
TimeInttomaxAN= (timeMaxAnteriorN*dt)-(xin);

%% tijd van max anterior tot eind
timeMaxAnteriorN= find (medRlevel(:,4) == MaxAnteriorN);
if max(size(timeMaxAnteriorN))>1
  timeMaxAnteriorN=timeMaxAnteriorN(1:1);
end
TimefromMaxAN= (xane)-(timeMaxAnteriorN*dt);
%% Totale staptijd
TotalStepN= (xane-xpnb)
%% ratio breedte grafieken
RatiobreedteN =(TimetoMaxPN+TimeMaxtoIntPN)/(TimeInttomaxAN+TimefromMaxAN)
%% tabel met gegevens
x = {
  'Parameter' 'Uphill' 'Downhill' 'Level' '' '' '';
  'Ratio between peaks' RatioHoog RatioLaag RatioLevel '' '' '' ;
  'Time difference between peaks' DifferenceH DifferenceL DifferenceN '' '' '';
  'time difference between HC and Max posterior' TimetoMaxPH TimetoMaxPL TimetoMaxPN '' '' '';
  'time difference between Max posterior to intersection' TimeMaxtoIntPH TimeMaxtoIntPL
TimeMaxtoIntPN '' '' '';
  'time difference between intersection and end posterior phase' TimeInttoendPH TimeInttoendPL
TimeInttoendPN '' '' '';
  'time difference between start anterior phase to intersection' TimestarttoIntAH TimestarttoIntAL
TimestarttoIntAN '' '' '';
  'time difference between intersection and max anterior' TimeInttomaxAH TimeInttomaxAL
TimeInttomaxAN '' '' '';
  'time difference between max anterior and end anterior phase' TimefromMaxAH TimefromMaxAL
TimefromMaxAN '' '' '';
  'total step time' TotalStepH TotalStepL TotalStepN '' '' '';
  'Ratio Width' RatiobreedteH RatiobreedteL RatiobreedteN '' '' '';
  '' '' '' '' '' '' '';
  'x,y values referetion points' 'X Uphill' 'Y Uphill' 'X Downhill' 'Y Downhill' 'X Level' 'Y
Level';
  'Start posterior phase' xphb yphb xplb yplb xpnb ypnb;
  'Max value posterior phase' WaardemaxPH MaxPosteriorH WaardemaxPL MaxPosteriorL WaardemaxPN
MaxPosteriorN ;
  'End posterior phase' xphe yphe xple yple xpne ypne;
  'Start anterior phase' xahb yahb xalb yalb xanb yanb;
  'Max value anterior phase' WaardemaxAH MaxAnteriorH WaardemaxAL MaxAnteriorL WaardemaxAN
MaxAnteriorN;
  'End anterior phase' xahe yahe xale yale xane yane;
  'Intersection' xih yih xil yil xin yin;}

B = input('Do you want to save the document? yes=1 no=2')
if B == 1;
  opslaan= input('onder welke naam?', 's')
  xlswrite(opslaan,x)
end
```