ANALYSIS OF PRODUCT DESIGN LONG LEG BRACES WITH KANSEI WORDS APPROACH AND BIOMECHANICS

Bellyn Mey Cendy[1)], Sugiono[2)], Dewi Hardiningtyas[3)]
Industrial Engineering, Universitas Brawijaya
Jalan MT. Haryono 167, Malang, 65145, Indonesia
E-mail: mcbellyn@gmail.com[1)], sugiono_ub@yahoo.com[2)], dewi.tyas@ub.ac.id[3)]

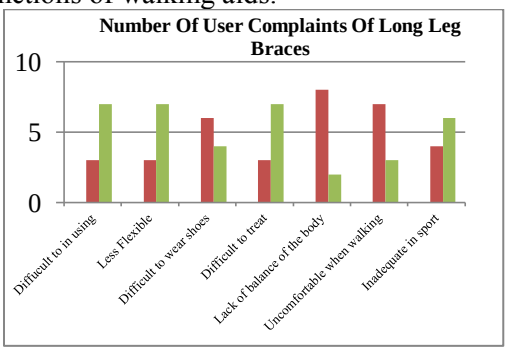
Abstract: *Many aspects become consideration related to the needs and desires of consumers with disabilities. Categories of persons with disabilities using using the lame use walking aids (long leg braces) for everyday mobility. Long leg braces that are now in the market have some complaints. Incompatibility use walking aids prove that the identification and analysis of existing of long leg braces as consideration for further improvement. When using the product, 40 of long leg braces become the sample from 64 populations in Malang. The consumer of long leg braces tend to express a desire using abstract words. Identification of the feelings and emotions of the users done using kansei words. Kansei words represent human psychological as feelings and emotions. Considerations that appear on kansei words, become consideration in the calculation of biomechanics. Therefore,it is expected that the design of the new long leg braces are able to distribute energy/ the load of the user so it can reduce complaints based on kansei words. Based on the kansei questionnaire there are 25 pairs of words that represent the desire of consumers to the product. 7 factors which produce ergonomic consideration factors have the most variable. Adjustments to the forces and moments between the segments of the normal foot greatest force in doubled phase support pelvic segment amounted to 28.93 N and moment of inertia of 658.53 KgM2. With a recommendation on long leg braces segment so that the resulting mass at the base of the thigh segment amounted to 0.864 kg, 0.792 kg calf and the foot segment amounted to 0.182 kg. Biomechanical calculations have proved that complaints of long leg braces have the highest number of complaints on the suitability of the thigh segment based on kansei words.*

Keywords*: long leg braces, human kansei, force distribution, kansei words, biomechanics*

1. Introduction

When consumers using a product, consumers assume that the products that are used will provide satisfaction in accordance with the wishes and needs. Ergonomics evaluation is one way of innovation of the products function that can provide a significant improvement.

In Indonesia, currently there are not a lot of studies that develop products for persons with disabilities. On the other hand it is an opportunity that should have the same attention to the design and development of products. Many persons with disabilities are not able to use regular products, which are not designed for them (Santrock, 2007). Thus the assessment of the load analysis products for persons with disabilities essentially need to be used to improve the performance of persons with disabilities in their daily activities. According to the Central Bureau of Statistics in East Java, the number of disabled persons in East Java was ranked second-worst, of 382 722 inhabitants with the specification number of people with lame in Malang are 139 people (Central Bureau of Statistics, 2011). The types of walking aids are the product that helps the accessibility and mobility for people with lame. The use of aids themselves have become a primary need for persons with disabilities. One of walking aids which also functions as a healing therapy is long leg braces. From previous research results obtained from 10 samples of users of long leg braces on preliminary survey data are (Herdiman, Liquiddanu, Paramitha, 2011), in Figure 1. There are 7 major complaint of the functions of walking aids.



Picture 1. Number of Consumer's Complaints of Long Leg Braces from 10 Sample of User

Noncompliance with walking aids of long leg braces are perceived by people with lame so that the necessary improvement of the design of long leg braces to improve the function and restore the desires of consumers with lame in using these tools. From the number of disabled people who are lame in Malang, now only 2 out of 5 people with necessity of using leg braces are still using the walking aids (Priest, 2014). A total of 80% correspondent preliminary survey claimed to have more than one leg braces but did not use it. Picture 2 An example of long leg braces walking aids which now in the market.

Picture 2. *Long Leg Braces*
(DINF, 2012)

Based on the problems above, it is necessary to do further research to improve the long leg braces walking aids that can increase the value of the products using biomechanics based on kansei words.

2. Research Methods

This study is divided into three stages, namely the initial identification, data processing and data processing kansei words biomechanics.

2.1 Identification of Early Stage

Early identification stage is divided into the following steps.
1. Observation
2. Literature
3. Identify the problem
4. Statements of the problem
5. Determination studies objectives

2.2 Data Collection

Data collection phase is divided into the following steps.
1. Type and source of data

Data used in this research are the primary data. Primary data are needed in between the interviews and questionnaires of kansei words. As well, the data of body dimensions of the long leg braces walking aids users.
2. Methods of data collection

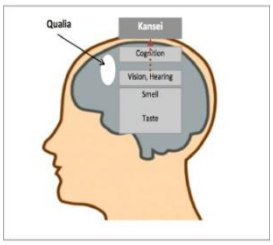
Methods of data collection in this research is to conduct interviews, observations and questionnaires.
3. Population and Sample

The population in this study is the number of long leg braces walking aids users which consists of two disabled community in Malang , they are 40 people.
4. The sampling technique

The sampling technique used in this study is Probability Sampling. The method of taking the sample using random sampling, which means sampling based group which has been determined from a random member of the population or by lottery. Based on the formula of Slovin in Umar (2005), the number of samples that should be taken is not less than 39 respondents.
5. Formulation of Scale

The scale used in this study is semantic differential scale within 5 points containing the values that are believed in each _ bipolar item (opposite) (Osgood, 2001)
6. Collection of Kansei Words

Long leg braces walking aids users when observations is conducted within 5-10 minutes. Then submit a complaint that is felt during using the braces. Figure 3. The process of Kansei Word Emerging. (Nagamichi, 2008)



Picture 3. Process of *Kansei Word*
(Nagamichi, 2008)
7. Body Data Dimensions

The collecting of body data dimensions randomly select the the long leg bracesusers' height. Because, the unique nature of the product so that it is different in size between each individual.

2.3 Data Processing

1. Data Test Sufficiency

After the questionnaires were distributed to 40 users of the long leg braces. Data test sufficiency is done to describe the number of

samples of all questionnaires distributed to respondents. Test of the data test sufficiency using the slovin formula because the number of known populations are 64 people.

$$n' = \frac{N}{1+N\,e^2},\ N > n' \ldots\ldots \ldots (1)$$

Specification:

n '= number of observations that should be done.

N = Number of population

E = Percentage leniency of inaccuracy due to sampling error which can still be tolerated (E = 100%)

2. Data Test Uniformity

Having in average of each sample in the population then get the score of BKA and BKB. This score used to determine the uniformity of the data in this research. With no score is out of control.

3. Test Factor Analysis

Factor analysis is a data reduction procedure in multivariate statistical techniques. Utilizing the relationship (correlation) between variables which will be used to form new variables fewer than initial variables. In other words, factor analysis used to summarize the information into a variable number of smaller synthesis and to find the axis of the semantic space after the evaluation of this Semantic Differential. In the concept of Kansei Engineering the result of the analysis of these factors will suggest (focus) on purposes in determining the items and categories of product design based on customer's feelings in kansei word. Words - will be reused on the Semantic Differential second evaluation. Software used in this process is SPSS 19.0.

4. Calculation of Mass And Long Legs

Based on Web Associaties and Dempster the mass value and the mass center point of the segment legs, thighs and calves are got. That will be used in the calculation of the distribution of forces and moment of inertia. Table 1 is based on the body mass distribution terms Dempster (1995).

Table 1. Distribusi Massa Segmen Tubuh

Group Segment (%) of Total Body Weight		**Individual Segment (%) of Group Segment Body Weight**	
Head and Neck	8.40 %	Head	73.8 %
		Neck	26.2 %
Torso	50.0 %	Thorax	43.8 %
		Lumbar	29.4 %
		Pelvis	26.8 %
Total Arm	10.20 %	Upper Arm	54.9 %
		Forearm	33.3 %
		Hand	11.8 %
Toral Leg	15.70 %	Thigh	63.7 %
		Shank	27.4 %
		Foot	8.9 %

5. Calculation Style and Moment of Inertia

Based on phase of human walking which experiencing abnormalities, there are four phases namely single support by normal , doubled single support braces front, single support by braces, and doubled single support by normal. Then do the projection distance between the two furthest toehold. By calculating the distance to the projection of each toehold.

6. Discussion and Analysis

At this stage, discussions were held from the results of the analysis of forces and moment of inertia when it is used to walk. Based on the calculation of forces and moment of inertia prove the factor that becomes improvements in data processing of kansei words.

7. Conclusions and suggestion

Making conclusions and suggestions on the data analysis and discussion that has been done so that it can answer the research objectives that have been set.

3. Results and Discussion

3.1 Processing of Data Test Sufficiency

Sufficiency test of the data will be distributed to the respondents. In this study, the population already known as 64 people so that the sample that should be taken is 39. Because the, score of n '<n then the data are sufficient.

3.2 Data Processing of Kansei Words

Data collection based on Kansei questionnaire on 40 samples of long leg braces users. there are 25 pairs of words. After doing the testing factors analysis rotation matrix factors and successfully classifying items of words into 7 main factors, namely, consideration Ergonomics consideration,

Consumer Ratings, Main Functions, Reliability of Products, Physical Display of Products, Product Design and Product Mechanism (DINF, 2012) . Based on the classification analysis of these factors, factors which have the highest number of items being a consideration in the subsequent data processing. Ergonomic consideration have most kansei words and ergonomic consideration have further identification to the study of biomechanics. Table 2. It is kansei words formed that have further consideration at the time the product is used by humans. The results of data processing Anti-image correlation, KMO-MSA score of these variables have fulfilled because it is above 0.5. To get the most important variables using levels of KMO-MSA level we can find the best variables. The more words that do not really matter it will be more difficult the respondents to understand. So that respondents tend to ignore the variable that is not too important. After knowning the eligible variables for further dinalisa. Extraction of a number of variablesto form a factor.

Table 2. Grouping Kansei Words

No.		**Factor 1**	**Nilai MSA**	***Kansei Word***
1	Ergonomics consideration	Item_5	.637	Soft-Hard
2		Item_1	.629	Light-weight
3		Item_8	.652	Simple-Complex
4		Item_9	.560	Automatic-Manual
5		Item_4	.551	Safe-Hazards
6		Item_6	.550	Healthy-Irritation
7		Item_10	.607	easy Safety - difficult safety
8		Item_12	.412	Keeping pants pants-Damaging pants
9		Item_13	.527	Modern-Ancient
10		Item_14	.648	Lancer hinge - jammed hinge.
11		Item_15	.638	Sophisticated - No sophisticated
12		Item_16	.575	Complete-Incomplete
13		Item_20	.290	New-Antique
14		Item_21	.474	Various-Monotone
No.	Consumer Ratings	**Factor 2**	**Nilai MSA**	Kansei Word
15		Item_3	.414	comfortable-Restless
16		Item_23	.509	Plain-colored
No.	Main functions	**Factor 3**	**Nilai MSA**	Kansei Word
17		Item-17	.473	One Function - Multi Function
18		Item_18	.582	Durable-Perishable
No.	Product Reliability	**Factor 4**	**Nilai MSA**	Kansei Word
19		Item_25	.545	Cheap - Expensive
20		Item_11	.624	Keeping pants pants-Damaging pants
No	Physical Display of Products	**Factor 5**	**Nilai MSA**	Kansei Word
21		Item_22	0.551	Interesting - Boring
No	Product design	**Factor 6**	**Nilai MSA**	Kansei Word
22		Item_7	.740	Simple - Complex
No		**Factor 7**	**Nilai MSA**	Kansei Words
23		Item_19	0.445	High technology - Low technology

Based on the output of the rotation factor that have been encrypted SPSS 19.0, so 7 factor that are enable the identification of factor become what is perceived by consumers to the long leg braces with. Factor 1 is a factor that are it compatibility with ergonomic considerations, factor 2 is an assessment of the current consumer products work, factor 3 is the primary function of the , factor 4 Reability or durability of, factor 5 is the physical appearance of a walking aid, factor 6 is the design of that is appropriate with the desires of consumers, and factor 7 is a mechanism of the tool aid when operated by users. Based on the processing of two rotated factor matrix kansei item has undergone the reduction in item 2 (coarse-Slick) and item 24 (Elegant-Ordinary). This is a kansei words variable that are not be a priority of the consumer complaints about this walking aids.

3.3 Processing of Biomechanics

Determination of object that is used in biomechanical calculations random selection. This is because the tools that are being studied in this research it unique properties, which it different sizes depend on the size of each individual body dimensions . As an approach to users complaints of long leg braces with in Malang so the selection of cases is dobe by distributing questionnaires to 20 users of long leg braces with lame. Figure 4 is a graphic of user complaints. Measured body segment. Thigh Length (thigh) from the groin to the knee, Calf Circumference which captured the largest calf size, Calf Length was measured between the knee and ankle, Foot Length was measured between the ankle and end thumb,

circumference malleolus (ankle circumference) foot wrist circumference, Midthigh circumference (thigh circumference) were measured at the largest circumference of thigh. In the measurement of body dimensions of the object of this study, it focuses on the legs of the body segments. As in generally happens, the dimension of lame or withered leg is shrinking than normal. the decreasing muscle mass due to never have movement. It causes most people that are lame is shrinking in the size of the leg segments.

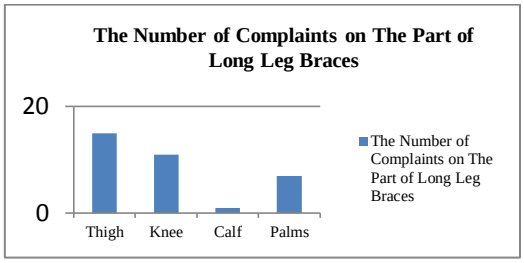


Figure 4. Number of _ Complaints of the Segment Feet users

Based on the approach to the users above there is most complaints occur in 15 people thigh palm segment, palm segment 11 people, calf palm segment 1 and palm segment 7 people. Then it is taken one of the objects of research for the measure the dimensions of body for the biomechanics data calculations. The object of research with 149 cm height and 45 kg weight. So with Web approach Accociateies (1978) there is the mass of each palm segment to the overall weight of the upper body become the toehold. As for the body follows the percentage of the mass center point Dempster (1995) are tabulated in Table 4. And body mass in Table 3.

Table 3. Body Mass

Body Segment	**Mass (Kg)**	
Body Weight	28,93	
eg	Right	Left
a. Thigh	4,70	5,56
b. Shank	2,60	1,80
c. Foot	0,80	0,61
Total	45,0	

Tabel 4. Data Panjang Tubuh

Long (cm)	
L(N)'	**L(N)"**
15.155	19.845
11.619	15.309
9.009	11.991
Long (cm)	
L(N)'	**L(N)"**
14.722	19.278
8.66	11.34
6.435	8.565

3.4 Modelling Walk

Modeling the abnormalities movement can be divided into four phases, Phase 1 (Single Support by Normal), Phase 2 (Doubled Support by Braces Front), Phase 3 (Single support by braces), Phase 4 (Doubled Support by Normal Front). 3.5.1 Single Phase Support by Braces In this first phase the right foot step perfectly formed 90º angle to the floor . The right leg is in stance position. While the left leg that uses braces forming an angle of 20º to the right foot. Long leg braces experience the most distant swing position . In this phase force and moment inertia are found in the joints of the hips, knees, and heels. Figure 6. Projection Style In Phase 1 (Source: Hertanto, 2006)

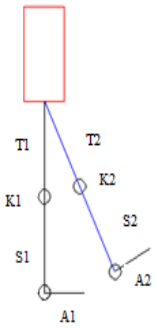


Figure 5. Segment of the whole body

Specification:

T1 = Right Thigh Length (Normal)
T2 = Left Thigh Length (Braces)
K1 = Right Knee (Normal)
K2 = Left Knee (Braces)
S1 = Right Calf Length (Normal)
S2 = Left Calf Length (Braces)
A1 = Right Heel (Normal)
A2 = Left heel (Braces)

3.5.1 Single Phase Support by Braces

Braces In this first phase the right foot

step perfectly formed 90º angle to the floor . The right leg is in stance position. While the left leg that uses braces forming an angle of 20º to the right foot. Long leg braces experience the most distant swing position . In this phase force and moment inertia are found in the joints of the hips, knees, and heels.

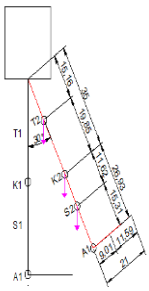


Figure 6. Projection Style In Phase 1
(Source: Hertanto, 2006)

3.5.2 Singled Support by Braces Phase

In the single support by braces phase it is described that the left leg which using braces perfectly step formed 90º angle to the floor . Long leg braces are in a stance position. While the right foot forming an angle of 30º to the left leg. Calf of right leg forming an angle of 100º to the thigh, while the palm of the foot forming an angle of 90º to the calf.

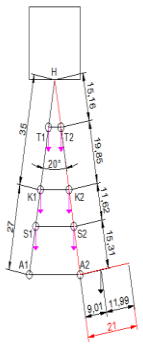


Figure 7. Projection of Style In 2
(Source: Hertanto, 2006)

3.5.3 Singled Support by Braces Phase

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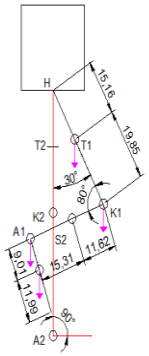

Figure 8. Projection of Style In Phase 3
(Source: Hertanto, 2006)

3.5.4 Doubled Support by normal Front Phase

In the single support by braces phase it is described that the left leg which using braces perfectly step formed 90º angle to the floor . Long leg braces are in a stance position.

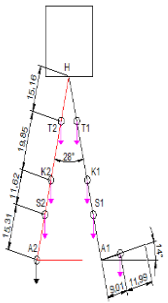

Figure 9. Projection of Style In Phase 4
(Source: Hertanto, 2006)

3.6 Calculation of Force and Moment

3.6.1 Phase 1 Single Support by braces

The force in a single support by normal phase shows the score of FNA1 (Normal leg ankle) is 1082.53 N. FNK1 (normal knee) is 913.19 N. FNH1 (pelvis) is 786.29 N. In this calculation the greatest force was in the ankle segment of normal foot. Calculation of moments in phase 1 (Single Support by Normal) is 111.17 Kg.M2 in all segment of thigh, leg, and calf are the same due to the furthest toehold distance is perpendicular to the normal foot.

3.6.2 Phase 2 Doubled Support By Braces Front Phase

The force on doubled support phase by braces front score of FNA1 - (normal leg) is 20.06 N, FNK1 (normal knee) is 25.64 N, the force on in the hip FNH is 28.93 N, and force of in the FNK2 (knee leg braces) is 21.84 N, and the forces work on the ankle FNA2 is 24.55 N. in

the calculation of force of doubled support by normal there is the highest score in the hip segment of knee (pelvis) this is due to the load strut by leg when using the tool in the segment of knee of hip and weakening of in the segment of knee and leg. the biggest Moment of inertia of was in hip which is 685.63 N.

3.6.3 Phase 3 Single Support By Braces

The force in the a single support by braces shows the score of FNA2 (normal Ankle Leg) is 183.21 N. FNK2 (normal knee) is 170.06 N. FNH (pelvis) is 146.30 N. In this calculation the greatest force was in the the ankle segment of normal foot. Calculation of moments in phase 3 (Single Support by Braces) is 52.46 N Kg.M2 in all segment of knee , thigh, leg, and calf are the same due to the furthest toehold distance is perpendicular to the normal foot.

3.6.4 Phase 4 Doubled Support By Front Phase

The force on doubled support by braces front score of FNA1 - (normal Ankle normal leg) is 20.06 N, FNK1 (normal knee Leg) is 25.65 N, the force on in hip FNH is 28.93 N, and force of in FNK2 (knee leg braces) is 21.84 N, and the forces work on the ankle FNA2 is 24.54 N. in the calculation of doubled support by normal phase there is the highest scores in segment of the hip (pelvis) this is due to the load which strut by leg when using the tool in hip segment and weakening segments of knee and leg. the biggest Moment of inertia of was in hip which is 645.19 N.

3.7 Analysis of Biomechanics

Biomechanics have principles which can be used for analyzing the forces and moments that work on each phase of the movement in the current use long leg braces to the joints segment. Figure 10. An image graphic of single support phase.

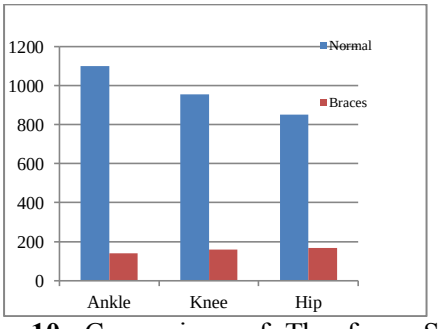

Figure 10. Comparison of The force Single Support Phase

The graph above shows the comparison of the normal force when the legs using long leg braces with the normal leg in the same position. It is seen that the highest score of the force that works on the ankle, knee and hip the do not use long leg braces is bigger than the leg the use long leg braces during the single support phase. Figure 11 is a graphic of moment of inertia on the the single support phase.

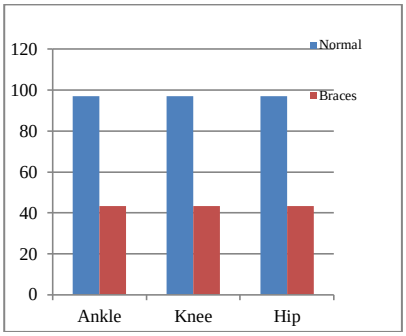

Figure 11. Comparison of Moment of Inertia In Single Support Phase

Comparison of the moment of inertia the happens between the leg using long leg braces with the normal leg. So it is got that the moment of inertia ratio at each joint of normal foot is much bigger than the leg that use braces. Differences of moment of inertia and normal force calculation is very significant, this happens due to the gravity and the position and angle that works differently in each movement. Figure 12. Shows the normal force that occurs in the doubled support phase.

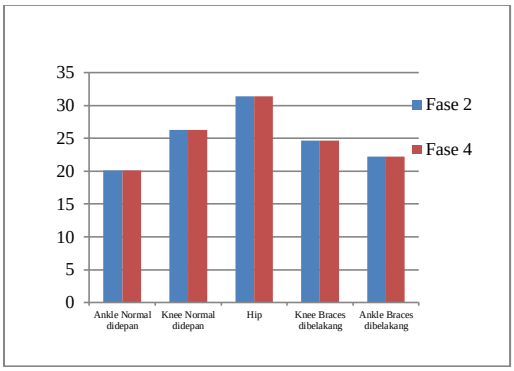

Figure 12. The Normal force In DS Phase

Normal force the occurs in doubled support involves the segment that uses working on the front so that the biggest toehold is hip or pelvis of of the users. While the four phase that is doubled support normal in the front and the toehold is the leg that uses long leg braces and has the score the same as the two: hip or pelvis

of the users. Figure 13. It is the moment of inertia calculation doubled support.

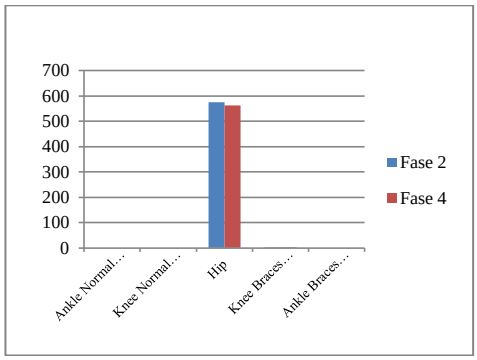

Figure 13. Moment of Inertia In Doubled Support Phase

Moment of inertia above shows the score on both phase two, that is doubled support support with the foot conditions in the front and four phase that is doubled support of normal foot in the front. From the graph above it can be seen that when the phase two, doubled support in the front moment of inertia happens at the hip same as the calculation of the normal force that works.

3.7 Proposed of Improvement Design of Long Leg Braces

Normal force and moment of inertia which work when of long leg braces used to walk have some differences. These are due to of two factors which influence the angle and the mass of the segments involved when walking. Phase of the single support of normal leg in the front and single support of normal leg in the back, there is a difference because when the single support braces are in the swing phase when the long leg braces knee does not bent, whereas the normal leg bents. The same thing happened during the doubled support phase , so that it gives an influence on the size of the angle of the hip joint that occurs. This score will certainly give effect to the normal force and moment of inertia at each joint in each phase. Each leg has a mass segment that will be a major problem to the normal force and moment of inertia .

Each leg has a mass segment that will be a major problem to the normal force and moment of inertia . It can be minimized when rebalancing the mass of each segment of the leg (Susan, 1995).

M_{Braces} Thigh = $|M_{Right\ thigh} - M_{left\ thigh}|$ = |4,70-4,29| = 0,41 Kg

M_{Braces} Calf = $|M_{right\ calf} - M_{left\ calf}|$ = |2,60-1,26| = 1,34 Kg

M_{Braces} Leg = $|M_{right\ leg} - M_{left\ leg}|$ = |0.80-0.43| = 0,36 Kg

The mass of each segment is known, then a comparison is done with the mass of long leg braces that are used by users. Table 5. Here is a comparison of the existing mass of the product with the proposed product.

Table 5. Comparison of the mass of the existing and proposed

Leg Segment	**Mass**		**Differences (Kg)**
	Existing	Proposed	
Thigh	1,274	0,41	0,864
Shank	0,548	1,34	0,792
Foot	0,178	0,36	0,182
Total	2,000	2,11	1,838

Based on the above data tabulation, then on each segment on the long leg braces which used, in fact there are differences with the proposed mass of long leg braces. It is seen from the thigh segment on the existing long leg braces that is 0.864 kg heavier than the weight of the thigh segment of long leg braces which now used. And the calf existing segment of long leg braces with the long leg braces proposal has a difference of 0.792 kg, the weight difference that is being supported by the thigh is allocated to the calf and the rest of it gets the allocated weight of foot palm where the existing product has a weight difference of 0.182 compared to the proposed product . So we know that the total weight difference of long leg braces proposed is 2,11 kg. Based on the biomechanics statics, this research produces recommendations of the using of the alignment adapters tools to minimize the force when the disability persons are walking . Meanwhile, this research determines the identification of users' complaints of long leg braces based on the kansei words approach in which the human kansei words appear based on the feeling and emotions. Based on the _ biomechanics statics, this research produces recommendations of the using of the alignment adapters tools to minimize the force when the disability persons

are walking persons with disabilities. Meanwhile, this research determines the identification of users' complaints of long leg braces phase kansei _ based on the kansei words approach in which the human kansei words appear based on the kansei words the feeling and emotions. Biomechanics approach becomes consideration and quantitative evidence of output of forces and moments on the body segment. And, on the recommendation of the weight of each segment in the product design of walking aids for persons with disabilities. complaint is perceived at a consideration of ergonomic factors product has a close connection to the calculation of the biomechanics. Further consideration of ergonomics have been identified from the distribution of forces and moments which finally adjusted to the height and weight of consumers. The influence of The biggest normal force and moment of inertia of the output of of the kansei words have also been associated to the size of the force that works on the doubled support by braces phase and the normal leg . , The biggest normal force and moment of inertia is at the hip. Proving the closely relation to the perceived heaviness in the thighs, because this phase sustain the overall weight and also strengthen the steps of segment of the lower limbs (knee and ankle).

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