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Product Analysis of Safety Belt and Body Harness Coconut Sugar Climber: An Ergonomic, Durability, and Economic Feasibility Principle

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ABSTRACT

Known as one of the largest coconut producers in the world, Indonesia has many coconut-producing regions. One of the areas that produces 85% of coconuts is Banyumas Regency. The leading product from this area is coconut sugar. However, the number of coconut farmers in Banyumas Regency has decreased due to the high number of work accidents. The Banyumas Regency Industry and Trade Office is looking for solutions to these problems by designing safety belts and body harnesses with three alternative packages. The purpose of this research is to analyze the product based on aspects of ergonomics, durability, and economic feasibility. Measurement of ergonomic aspects based on work posture analysis, anthropometry, and usability. Meanwhile, to measure the durability aspect based on the tensile test. Economic feasibility analysis based on a comparison of the selling price of each alternative. Furthermore, determining the most optimal product package using Analytical Hierarchy Process (AHP). The results showed that all products require improvement for ergonomic aspects, are able to withstand loads >400kg based on tensile tests, and have selling prices ranging from Rp350,000.00 - Rp750,000.00 for each package. Based on AHP analysis, the optimal alternative is the second package. AHP analysis based on ergonomics, durability, and economic feasibility.

1. INTRODUCTION

Indonesia is known as an agricultural country [1]. This is because the agricultural sector contributes significantly (12.40%) to the national economy [2]. It shown by the positive growth of this sector from 2020 to 2022. In 2020 this sector grew by 1.77%, then in 2021 grew by 1.87%, and in 2022 grew by 2.25% [3]. These are because currently agriculture is a source of livelihood for most of the Indonesian population, currently many industries in Indonesia are still dependent on raw materials in the agricultural sector, besides that many commodities spread throughout Indonesia [4]. One of the main agricultural commodities that has various benefits is coconut [5, 6]. Indonesia is known as one of the world's largest producers of coconuts [7]. One of processed product of coconut that has an important role to the culture and economy in some regions is coconut sugar [8, 9].

Banyumas Regency is the center of coconut sugar in Central Java, Indonesia. More than 85% of the districts are coconut sugar producers [10]. The products are distributed locally and internationally according to the quality of the coconut sugar [11, 12]. Data from Department of Agriculture and Food Security of Banyumas Regency shows that the highest production of coconut sugar is in Cilongok District that reach 200t/month on the 807.50ha harvest area [13-15]. Thus, makes majority of Banyumas people have the occupation as coconut sugar farmers [14, 16]. However, the number of coconut sugar farmers is decreasing year by year [17]. According to Department of Industry and Trade of Banyumas there are 27.117 farmers in 2014, 26.282 farmers in 2015, and 20.293 farmers in 2017 [11, 14]. This is due to the high number of workplace accidents faced by coconut sugar farmers, which has reduced regeneration in this occupation [14, 18]. Based on data from the People's Welfare of Banyumas Regency (2020), from 2017 to 2019 there were 323 cases of work accidents among coconut farmers (236 physical disabilities and 87 deaths) [18-22] showed that work accidents occur due to a lack of knowledge and awareness to prevent work accidents.

Work accidents can cause both material and life losses, therefore, to minimize this, it is necessary to manage and control the risk of hazards that occur in the workplace [23]. One prevention is to use Personal Protective Equipment (PPE) when working [24]. Thus, it is required to develop tools and safety equipment for climbing and descending coconut trees in which include safety belt and body harness. The Banyumas Regency Industry and Trade Office as an agency responsible for the condition of coconut sugar farmers in Banyumas Regency seeks to provide solutions to these problems by designing seat belts and body harnesses with three packages with different specifications. The package has some prototype product. The prototype has three combination packages. The combination formed that the product supporting each other to covering each lack. The combination product package can see in Table 1. Therefore, to accommodate the needs, conditions,

and desires of coconut sugar farmers, a product analysis was conducted.

The objective of this study is to analyze the product based on aspects of ergonomics, design strength, and economic feasibility. The result of this research shows the most optimal package. The three aspects were resulted through preliminary research. Ergonomic aspects are measured by work posture analysis, anthropometry, and usability testing. For the design strength aspect, it is measured based on the tensile test analysis. As for the economic feasibility aspect, it is measured by analyzing the economic value of the product.

Previous researches [25-27] presented the design of coconut tree climbing equipment, while Dhafir et al. [28], Sethuramalingam and Shine [29] conducted research related to REBA and work motion analysis on coconut tree climbing aids. Meanwhile, Nag et al. [30] designed agricultural equipment by implementing ergonomic aspects based on anthropometry and biomechanics. Based on the literature review above, it is known that there are similarities in terms of product design and analysis of coconut tree climbing tools. However, it is known that no one has conducted an analysis by linking the ergonomic, economic, and durability aspects of safety belt and body harness products.

2. METHODOLOGY

This research only consists about choosing the most optimal alternative package. The research method consists of four stages: preparation, data collection, data processing, and data analysis. The preparation stage begins with preparing a product test design scheme for safety belt and body harness by the Department Industry and Trade of Banyumas Regency. There are three product testing packages in which there are various types of safety belts and body harnesses. Literature study is carried out at this stage to obtain information about occupational safety and health systems, methods used, and testing techniques on each variable.

Furthermore, data collection is carried out on each test. In the ergonomic test, work posture is measured by Rapid Entire Body Assessment (REBA) method to determine the level of risk of work posture. To validate the suitability of product dimensions and the worker body dimensions using anthropometric analysis. The usability testing is conducted to determine the level of product usability. The tensile test was conducted by measuring the strength of each product. The last for the economic feasibility test was conducted by comparing the cost details of each package.

The next stage is data processing and analysis to determine the best solution that can accommodate the needs of coconut sugar farmers. Determination of the most optimal product package using Analytical Hierarchy Process (AHP). The analysis AHP using super decision application.

Table 1. Specimen product packages

Product Package	Product
Package 1	Li-Ao Harness (Figure 1) Horizontal Safety Belt Climber (BOX X3) (Figure 2)
Package 2	S&L Harness (Figure 3) Diagonal Safety Belt Climber (Figure 4) Webbing Rope (Figure 5)
Package 3	Carabiner Horizontal Safety Belt Climber (BOX X3) (Figure 2)

2.1 Subject and object

The subjects in this study were coconut sugar farmers that sheltered by the Banyumas Regency Industry and Trade Office. While the object of this study is coconut climber safety belt and body harness products (Table 1).

Figure 1. Harness Li-Ao

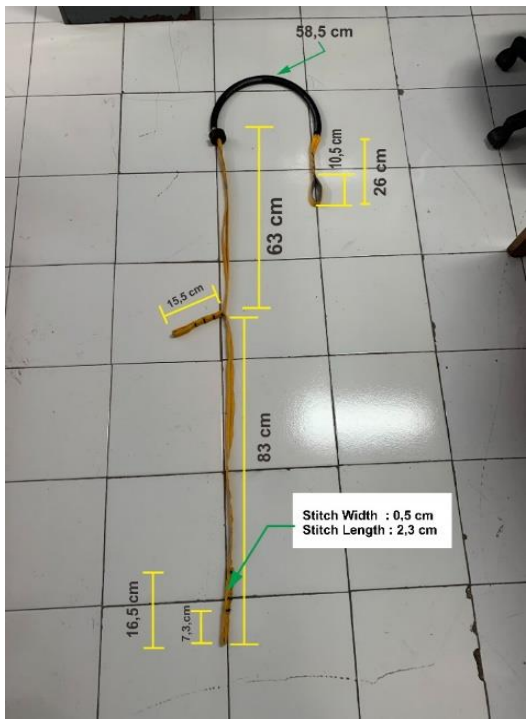

Figure 2. Safety belt climber horizontal (BOC X3)

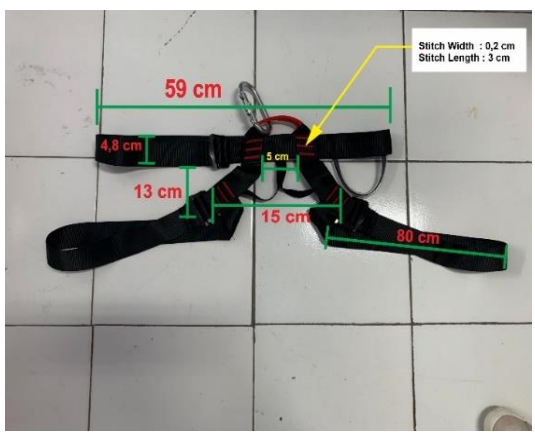

Figure 3. Harness S&L

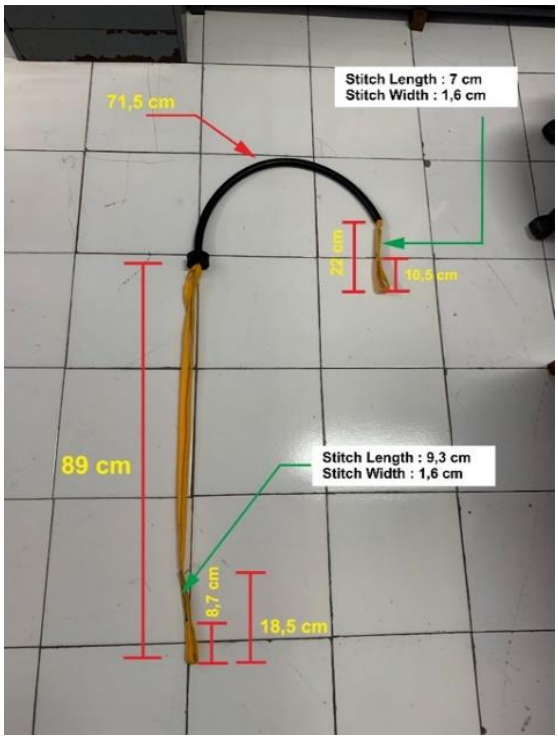

Figure 4. Diagonal safety belt climber

Figure 5. Webbing rope

Table 2. REBA score risk classification

Score	Level of Risk
1	Negligible risk
2 or 3	Low risk, change may be needed
4 or 7	Medium risk, further investigation, change soon
8 to 10	High risk, investigate and implement change
11 or more	Very high risk, implement change

2.2 Work posture test

The Rapid Entire Body Assessment (REBA) method is used to assess work postures affected by coupling factors and external loads supported by the body during activities [31]. Videos and pictures of climbing postures were analyzed. First, the angles of the body, neck, legs, upper arms, forearms and wrists were determined. Next, the angle data was processed using ErgoFellow 3.0 software. The results of these calculations were classified on the risk level table (Table 2) based on the resulting REBA score. There are two limitations of work posture testing in this study: (1) the study not analyzing images (work postures) with straight and side position; (2) This study only analyzing activities when climbing position.

2.3 Anthropometric test

Anthropometry is the study related to measuring the dimensions of human body to determine the appropriate product size [32]. Testing begins by measuring the dimensions of each product (diagonal safety belt climber, horizontal safety belt climber, Li-Ao harness, S & L harness, and webbing rope). All products were measured at their maximum dimensions to accommodate the largest user. Then, the results were compared to the human body dimension at 5^{th}, 50^{th}, 95^{th} percentiles.

2.4 Usability test

Usability testing is carried out to measure the ease of use of products operated by certain users to achieve goals effectively, efficiently, and satisfactorily. Usability testing was carried out on 9 expert judgment people related to the subject and object of research. The usability testing measuring instrument used in this study is an adaptation of the USE questionnaire by Lund [33]. The attributes measured in this test are usability, ease of use, and satisfaction. These attributes are measured through an assessment of the 11 statements listed in Table 3. The questionnaire assessment uses a Likert scale from 1 to 5 (1 = strongly disagree and 5 = strongly agree).

Table 3. USE questionnaire

Attributes	Question	Code
Usefulness	This product can help me be more effective in doing the job of collecting coconut sap	Q1
	This product has the features/functions I need	Q2
	This product can help me save time when doing the work of taking coconut sap	Q3
Ease of use	This product was immediately easy for me to use the first time I used it	Q4
	I do not need a long time to use this product	Q5
	I can recall how to use this product over a long period of time	Q6
Satisfaction	This product makes the job of collecting coconut sap easier	Q7
	This product makes the job of collecting coconut sap easier	Q8
	This product is a very necessary product in doing the work of taking coconut sap	Q9
	This product is suitable for recommending to others	Q10
	I am interested in using this product to do the work of collecting coconut sap	Q11

2.5 Tensile test

Tensile tests are intended to determine the strength of materials through different simulated design schemes. These tests yield the maximum force and load that each product can

accommodate. This test uses a testing machine. The before and after conditions of the products are compared.

2.6 Product economic test

The economic feasibility aspect was tested by comparing the selling price of each package. The selling price is generated from the sum of material costs and vendor costs.

2.7 Decision analysis

Analytical Hierarchy Process (AHP) is used to determine the optimal product package based on these three aspects. The decision was generated by the hierarchy of the problem and the weights of the three measured criteria. The package that has the weight closest to the optimal value (1.00000) is selected as the best package. AHP process using super decision application.

3. RESULT AND DISCUSSION

3.1 Ergonomic aspects

3.1.1 Work posture analysis

The results of testing work postures using the REBA method only analyze the angle of the posture formed during the coconut climbing process shown in Figure 6. The scoring REBA using ErgoPlus application which has final score is 11. The REBA value in the work position is 11 which indicates that the posture formed when using or not using the product is included in a dangerous work attitude and has a high risk of work accidents. The value was obtained based on several awkward posture conditions. The bad neck position in the extension state is 20.37°, and the back in the extension state is 4.53°. Then the angle of the foot when bent was 107.98°, the angle of the upper arm was 63.90° with additional abduction posture, the angle of the forearm was 86.93°, while the angle of the wrist was 45.17° with additional posture of wrist bending and coupling in the poor category due to consideration of unacceptable hand grip even though it is possible. An additional external activity factor is the presence of movements that require repetition more than four times a minute. Thus, the REBA score is classified in the high-risk activity criteria and requires immediate changes. The change action taken is to provide Personal Protective Equipment (PPE) to fulfill comfort and safety. This PPE is implemented in the form of safety belts and body harnesses for climbing coconut trees.

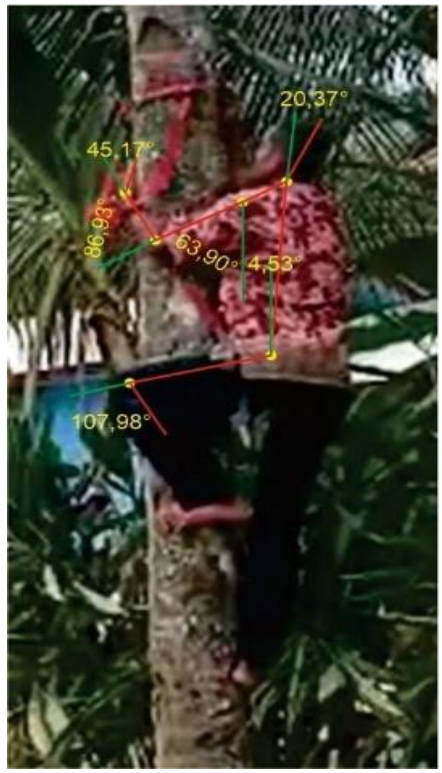

Figure 6. Climbing coconut tress work posture

3.1.2 Anthropometric analysis

The comparison between the product and user body measurements shown in Table 4. Based on the measurement results, it is known that almost of safety belt products dimension are in accordance with the anthropometric measurement standards of adult body, thus they can accommodate the largest user population (95th percentiles). However, the diagonal climber safety belt can only be used for the smallest population (5th percentiles). As for the webbing rope, it cannot be tested using anthropometric analysis because its size can be change which is influenced by the shape of knot used. The knot shape is an uncontrolled variable in this study.

Table 4. Result of anthropometry measurement

Product	Product Dimension	Anthropometric Dimension	Percentile		
			5th	50th	95th
Diagonal climber safety belt	89cm	Upward grip height in seated position	80.24	113.42	146.61
Horizontal climber safety belt	156cm	Upward grip height in seated position	80.24	113.42	146.61
Li-Ao harness	62cm	Hip width	21.65	32.32	43
	82cm	Thigh thickness	3.75	14.70	25.65
S & L harness	59cm	Hip width	21.65	32.32	43
	80cm	Thigh thickness	3.75	14.70	25.65

3.1.3 Usability analysis

The usability test results show that the response of each respondent to the product varies, with an average score of 36 using question in Table 5. The maximum score for 11 statements is 55. The average score of 65.45% with a deviation of 5 indicates that the product can still be developed to meet user needs. Based on the usability assessment, nine respondents considered that using the product requires more time for work preparation. This is indicated by the range of scores on statement Q3 which has a very low value (score 2 = disagree to 1 = strongly disagree). Meanwhile, statement Q4 has a fairly low score value because 8 out of 9 respondents rated it in the score range 3 = disagree to 2 = disagree). This indicates that respondents are not yet familiar with the use of product operations. The results of usability testing show that of the three usability attributes, respondents assess that the

product has fulfilled the satisfaction attribute, followed by the effectiveness attribute and finally the ease of use. The results of descriptive statistical analysis show that the three attributes are still below the value of 4 (agree) so that it can be interpreted that the product has not been able to meet user needs.

Table 5. Usability question

Attributes	Questions	Code
Usefulness	This product can help me be more effective in doing my job of collecting coconut sap	Q1
	This product has the features / functions that I need	Q2
	This product can help me save time when doing the job of collecting coconut sap	Q3
Ease of use	This product was immediately easy for me to use the first time I used it	Q4
	I DON'T need a long time to use this product	Q5
	I can remember how to use this product for a long time	Q6
Satisfaction	This product makes the job of collecting coconut sap easier	Q7
	This product makes the job of collecting coconut sap safer	Q8
	This product is a product that is really needed in carrying out the work of collecting coconut sap	Q9
	This product is suitable to be recommended to others	Q10
	I am interested in using this product to do the job of taking coconut sap	Q11

3.2 Strength aspect

Strength aspect was measured by conducted the tensile test on each product. The result of each product as follows.

3.2.1 Webbing rope

The webbing rope is used with the knot method and it can be assumed that the critical area of the webbing strap covers each sheet. Thus, the test is performed on all surfaces of the webbing rope. The test is performed twice using the same method. Preparation The webbing strap was cut to a length of 23cm. The webbing strap was gripped on both sides with a gripping distance of 100mm and a tensile speed of 100mm/min.

The difference between the initial condition and after the test showed that the webbing rope after the test was damaged at the bottom in the area near the bottom gripper. As for the test results, it was found that the webbing rope can withstand a load of up to 4,000N equivalent to 407kg.

3.2.2 Horizontal safety belt climber (BOC X3)

The horizontal seat belt climber was tested twice with differences in seat belt length and grip distance. In the first test, the seat belt was cut to a length of 33cm for the sample. As for the second test, the length was 28cm. The grip distance in the first test was 300mm and for the second test was 250mm. The tensile speed in both tests had no difference (100mm/min).

No.	F_H N	ε_H %	F_B N	ε_B %	a mm	b mm
2	4730	31,5	1510	66,0	3,6	24

Series graph:

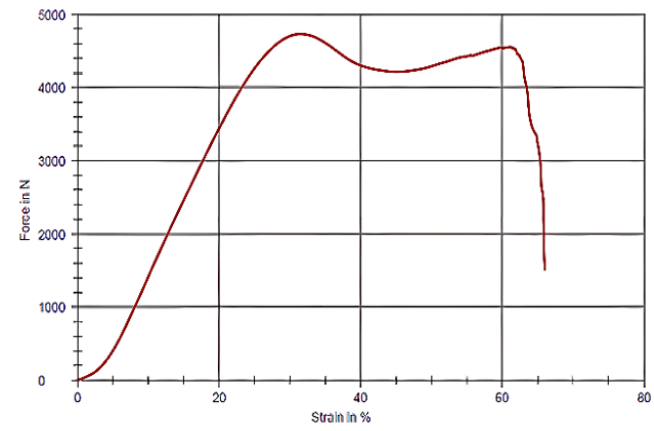

Figure 7. Force and strain horizontal safety belt climber

The results of the first test showed that the seat belt stretched too long and almost reached the maximum engine stroke length. Therefore, the seat belt was stretched and deformed, especially in the area of the two layers before the connection seam. After removal, it can be seen that the seam between the layers is damaged. The test results show that the horizontal climber seat belt in the first test has not broken, still able to withstand the maximum force of 4,160N equivalent to 470kg.

In addition, in the second test, the seat belt did not break simultaneously. The second test had the same deformation area as the first test. Figure 7 shows that the seat belt in the second experiment had the highest force at 4,730N or equivalent to 482kg.

3.2.3 Diagonal safety belt climber

The diagonal seat belt climber was tested twice. The product was pulled at a grip distance of 250mm and at a speed of 100mm/min. The results of the two tests had different conditions after the test. In the first test specimen, it was found that the belts broke simultaneously. While in the second test, one of the belts broke first. Based on the graph in Figure 8, it can be seen that the diagonal safety belt climber is able to withstand a maximum force of 4,980N which is equivalent to 507kg.

Legend	No.	F_H N	ε_H %	F_B N	ε_B %	a mm	b mm
	1	4990	30,8	3370	42,1	2,3	26
	2	4980	32,5	2290	63,0	2,3	26

Series graph:

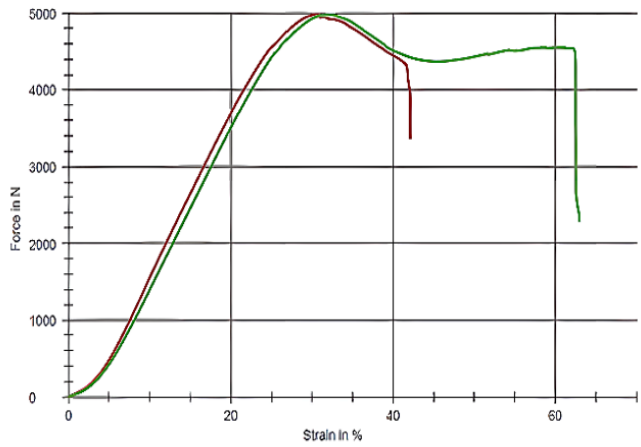

Figure 8. Force and strain diagonal safety belt climber

No.	F_H N	ε_H %	F_B N	ε_B %	a mm	b mm
1	14800	15,1	14600	15,3	2,3	26

Series graph:

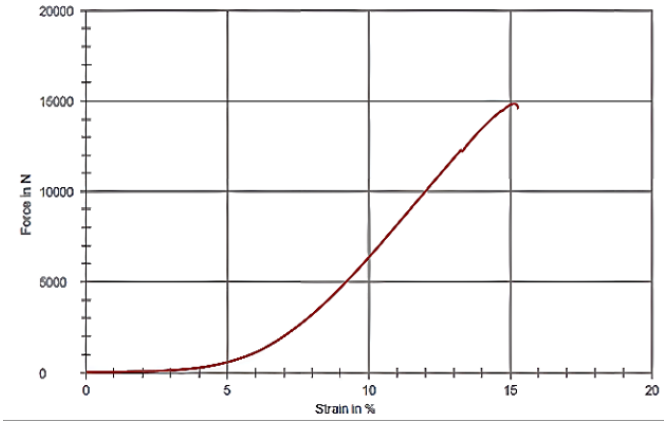

Figure 9. Force & Strain Li-Ao and S&L Harness (1st Test)

3.2.4 Li-Ao and S&L harness

Body harness testing was conducted twice. The differences between those tests are on the areas were tested and the gripping distance. As for the gripping distance in the first test as far as 250mm and for the second test as far as 170mm. Both of tests has the same tensile speed of 100mm/min. The result of the first test showed that the harness was detached from the grip. The harness reached the maximum load of 14,800N which equivalent to 1,509kg (Figure 9). While in the second test it was shown that the harness stopped because the tensile test had reached the maximum machine capacity of 17,000N or equivalent to 1,733kg (Figure 10).

No.	F_H N	ε_H %	F_B N	ε_B %	a mm	b mm
2	17000	16,8	-	-	2,3	26

Series graph:

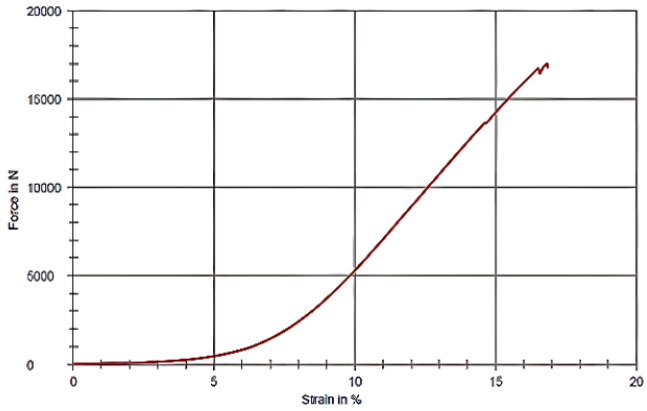

Figure 10. Force & Strain Li-Ao and S&L harness (2nd Test)

Table 6. Comparison alternate ergonomic, strength or economic analysis methods

Package Product	Description of Product Contents	Tensile Test	Ergonomics Test	Economic Test
1st	Ao Harness & Safety Belt Climber Horizontal (BOC X3)	Maximum load that can be detained is as big as 450 kg as limit it's safe. Due part that will moreover Formerly experience damage material is on the safety climber.	Required caring development comfort and security product especially from aspect materials (for all Package) and size (custom For Packages 2&3) for posture from her body is medium climb No feel pain excessive with exists use safety belt.	Price: Rp. 750,000 Details: Material Total: Rp. 481,000 Vendor Price: Rp. 269,000
2nd	S&L Harnesses & Diagonal Safety Belt Climber	Maximum load that can be detained is as big as 480 kg as limit it's safe. Due part that will moreover Formerly experience damage material is on the safety climber.	Although product This Not yet truly answer the needs of the respondents. However, the parameters of effectiveness and ease of use must become attention main from development next, cause these two parameters assessed Not yet effective and easy used by the respondent's moment first time trying nor moment will use tools (efficiency time from use tool).	Price: Rp. 400,000 Details: Need Material Total: IDR 281,000 Vendor Price: Rp. 119,000
3rd	Webbing Rope & Safety Belt Climber Horizontal (BOC X3)	Maximum load that can be detained is as big as 407 kg as limit it's safe. Due part that will moreover Formerly experience damage material is on its Webbing Rope.		Price: Rp. 350,000 Details: Need Material Total: Rp. 185,000 Vendor Price: Rp. 165,000

3.3 Economic feasibility aspects

The economic aspect is measured by comparing the selling price of the package, which consists of material and vendor costs. Material costs are determined from the ratio of needs to the total amount in one purchase. Meanwhile, vendor costs are production costs that include sewing materials. The first package, which includes the Li-Ao harness and horizontal safety belt climber (BOC X3), has a selling price of Rp750,000. This selling price consists of material costs (Rp481,000.00) and vendor costs (Rp269,000.00). Meanwhile, the second package consisting of the S & L harness and diagonal safety belt climber has a selling price of Rp400,000, which consists of material costs (Rp281,000) and vendor costs (Rp119,000).

For the last package consisting of webbing rope, carabiner, and horizontal safety belt climber (BOC X3) has a selling price of Rp350,000.00 with material costs of Rp185,000.00 and vendor costs of Rp165,000.00, and details of the comparison is shown in the Table 6.

3.4 Decision analysis

Table 7 shows the results of the Analytical Hierarchy Process (AHP) method. Based on the test results, it is known that the first package has a weight value of 0.995845, the second package is 1.000000, and the third package is 0.294736. This ideal weight is obtained from considering the test results of the three aspects (ergonomics, strength, and economic feasibility). Based on these results, it is known that the second package has the same ideal weight value as the optimal value (1.000000). This indicates that this package is the optimal choice. Meanwhile, the first package has an ideal weight value that is close to the optimal value. Then, the third package has the lowest ideal weight value compared to the other packages.

Table 7. Analytical Hierarchy Process results

Product Package	Ideal Weight Value
Package 1	0.995845
Package 2	1.000000
Package 3	0.294736

3.5 Overall analysis

The results of ergonomics testing it shows similarities between each package. The packages should have an intention on product comfort and safety by its materials. Meanwhile for the second and the third package have to improve the size aspect. These two aspects must be fulfilled to accommodate climbing activities without pain while using the products. In addition, the developers should be focused on products usability aspects. The products still have problem on effectiveness, ease of use and comfort while using the products. There are some solutions to overcome the problems on ergonomics aspects:

(1) Redesign the hook on the safety belt climber, that can eliminate some non-values added activities;

(2) Foam can be added to certain parts of the harness to minimize possibility skin injured while using it in a long time;

(3) Increase the size length on the safety belt climber especially on horizontal safety belt climber. Thus, it can accommodate more user's population.

The first package can hold a maximum load of 405 kg with a selling price of Rp750,000. Meanwhile, the second package is able to accommodate loads of up to 480kg with a selling price that is much cheaper than the previous package, which is Rp400,000. Furthermore, the third package is the cheapest with a price of Rp350,000 with a maximum load of 407kg. Based on the design strength aspect, it is known that all packages have a maximum load of >400kg. If the load is more than this number, there is a possibility that the product material can be damaged. Meanwhile, from an economic point of view, it is known that there is a very large range between the selling price of the first package and the other packages.

Overall, the results and analysis of an ergonomic, strength, and economic feasibility aspect are taken into the decision analysis. The Analytical Hierarchy Process (AHP) results show that the most potential alternatives package is the second one.

4. CONCLUSION

Products improvements are necessary to accommodate the ergonomic aspects. According to the tensile test analysis the load of each package capable to withstand > 400kg weight. The price on the first package is significantly different with the other two packages hence to the difference in material and vendor costs. The decision based on AHP analysis shows that the second package is the most optimal alternative package. So, the Banyumas Regency Industry and Trade Office can cooperate with local industries to massively producing the second package which making coconut farmer more productive.

There are a few ways to get around the issues with ergonomics:

(1) Redesigning the safety belt climber's hook can eliminate some non-value-added activities;

(2) Adding foam to specific parts of the harness can reduce the chance of skin injuries from prolonged use;

(3) Lengthening the safety belt climber's size, especially for horizontal safety belt climbers. As a result, it can support a larger user base.

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REFERENCES

[1] Rozaki, Z. (2021). Food security challenges and opportunities in Indonesia post COVID-19. In Advances in Food Security and Sustainability, pp. 119-168. https://doi.org/10.1016/bs.af2s.2021.07.002

[2] Musyaffa, N.F., Myarta, L.R., Paksi, A.K., Iswari, R.D. (2023). The agricultural sector in Indonesia amidst COVID-19: Crisis or opportunity? E3S Web of Conferences, EDP Sciences, 444: 02054. https://doi.org/10.1051/e3sconf/202344402054

[3] PIS AGRO. (2023). Agricultural Census 2023 for the Better Indonesia's Agricultural Policy-making.

[4] Sari, M.I., Sundarta, M.I. (2023). Observation of agricultural business conditions in RT 05 Parakan Jaya village in economic terms during the Covid-19 pandemic. Agribusiness Management Knowledge, 2(1): 17-20. https://doi.org/10.32832/amk

[5] Anggrasari, H., Sari, A.K., Arminda, F.R. (2023). Indonesian coconut oil export opportunities with main trade partner countries in the international market. Buletin Penelitian Sosial Ekonomi Pertanian Fakultas Pertanian Universitas Haluoleo, 25(1): 44-55. https://doi.org/10.37149/bpsosek.v25i1.445

[6] Abeysekara, M.G.D., Waidyarathne, K.P. (2020). The coconut industry: A review of price forecasting modelling in major coconut producing countries. CORD, 36: 17-26. https://doi.org/10.37833/cord.v36i.422

[7] Rahmawati, E., Nuraini, C., Mutolib, A. (2023). Export competitiveness of Indonesian copra in international trade 2017-2021. East Asian Journal of Multidisciplinary Research, 2(9): 3621-3630. https://doi.org/10.55927/eajmr.v2i9.6134

[8] Amrina, A., Fausayana, I., Limi, M.A. (2023). Value-

added analysis and affecting factors coconut sugar offers (Case study: Coconut sugar maker in Manyampa village Ujung Loe district Bulukumba regency). Jurnal Ilmiah Membangun Desa dan Pertanian, 8(3): 110-116. https://doi.org/10.37149/jimdp.v8i3.411

[9] Alouw, J.C., Wulandari, S. (2020). Present status and outlook of coconut development in Indonesia. In IOP Conference Series: Earth and Environmental Science, 418(1): 012035. https://doi.org/10.1088/1755-1315/418/1/012035

[10] Faizah, V.N., Darwanto, D.H., Waluyati, L.R. (2020). Feasibility of coconut sugar business in Cilongok Sub-District, Banyumas Regency. Journal of Agribusiness Management and Development, 1(1): 19-27. https://journal.ugm.ac.id/v3/JAMADEV/article/view/960.

[11] Imran, R.A., Purnamasari, A.D., Sibarani, A.A., Soedirman, J., Karangwangkal Purwokerto, J.S. (2019). Analisis postur kerja posisi memanjat pada petani gula kelapa kabupaten banyumas. Jurnal Media Teknik & Sistem Industri, 3(2): 49-58. http://jurnal.unsur.ac.id/index.php/JMTSI.

[12] Badriah, L.S., Arintoko, A., Rahajuni, D. (2022). Decreasing return to scale in cottage industries: Empirical evidence from the coconut sugar industry in Banyumas, Indonesia. Journal of Asian Finance, Economics and Business, 9(7): 0219-0229. https://doi.org/10.13106/jafeb.2022.vol9.no7.0219

[13] Astuti, A.T. (2021). Peran lembaga penelitian dan pengembangan sumber daya & lingkungan hidup (LPPSLH) dalam pemberdayaan petani penderes. Jurnal Analisa Sosiologi, 9. https://doi.org/10.20961/jas.v9i0.41961

[14] Naresti, A., Irawan, A., Fatin, N.A., Qisthani, N.N. (2022). Identifikasi kecelakaan pada penderes gula kelapa guna menggunakan metode hirarc (studi kasus di banyumas). Jurnal TRINISTIK: Jurnal Teknik Industri, Bisnis Digital, dan Teknik Logistik, 1(1): 22-28. https://doi.org/10.20895/trinistik.v1i1.451

[15] Arman, A., Agustin, H., Karim, M., Kurniawan, O., Purwandaya, B. (2020). The sundown of home economical cilongok village: Case of coconut farm agriculture. IOP Conference Series: Earth and Environmental Science, 486(1): 012004. https://doi.org/10.1088/1755-1315/486/1/012004

[16] Prastyanti, S., Subejo, S., Sulhan, M. (2020). New media access and use for triggering the farmers capability improvement in central java Indonesia. Humanities and Social Science Research, 3(1): 1. https://doi.org/10.30560/hssr.v3n1p1

[17] Novarianto, H., Tulalo, M.A., Mawardi, S. (2021). Preliminary investigation of the potential of coconut sugar production using dwarf varieties. CORD, 37: 23-32. https://doi.org/10.37833/cord.v37i.444

[18] Renleeuw, J., Nurgiyanti, T., Subandi, Y. (2023). Strategi LPPSLH (lembaga penelitian pengembangan sumber daya dan lingkungan hidup) dalam Mengadvokasi Para Petani Gula Kelapa di Purwokerto. PRIMER: Jurnal Ilmiah Multidisiplin, 1(2): 106-112. https://doi.org/10.55681/primer.v1i2.57

[19] Ulfah, N., Dardjito, E., Harwanti, S., Parmasari, D.H. (2023). Work accident at sugar farmers in Banyumas Regency. Kemas, 18(3): 349-355. https://doi.org/10.15294/kemas.v18i3.35487

[20] Aji, B., Masfiah, S., Harwanti, S., Ulfah, N., Minh, H.V. (2023). Situational analysis of the extending national health insurance coverage to informal sector in Indonesia: A case study among palms sugar farmers. Journal of Health Research, 37(1): 55-61. https://doi.org/10.56808/2586-940X.1017

[21] Asshaf, M.N.R. (2020). Analisis Faktor Risiko Kecelakaan Kerja pada Petani Penyadap Pohon Aren atau Arenga Pinnata Menggunakan Metode Hazard Identification Risk Assessment and Risk Control. http://jurnal.globalhealthsciencegroup.com/index.php/JPPP.

[22] Chaiklieng, S., Suggaravetsiri, P., Poochada, W., Thinkhamrop, W., Dacherngkhao, T. (2022). The burden of work-related diseases and injuries among agriculturists: A three-year retrospective study in Thailand. Safety, 8(4): 78. https://doi.org/10.3390/safety8040078

[23] Priyanka, V., Basaria, F.T. (2023). Minimizing work risks in Indonesia: A case study analysis of hazard identification, risk assessment, and risk control implementation. E3S Web of Conferences, EDP Sciences, 426: 01017. https://doi.org/10.1051/e3sconf/202342601017

[24] Fatimah, N.A., Nurwijayanti, N., Farida, S. (2019). Analysis of knowledge, attitude, employee action in the use of personal protective equipment (PPE) with work accidents. Journal for Quality in Public Health, 3(1): 167-175. https://doi.org/10.30994/jqph.v3i1.60

[25] 'Ain Yahaya, S.N., Azlan, A. (2023). Design and analysis of coconut tree climbing bike using reverse engineering technique. Journal of Sustainable and Manufacturing in Transportation, 3(1): 30-39. https://doi.org/10.30880/jsmt.2023.03.01.004

[26] Pawar, M.R., Jagadale, O.A., Chakor, S. (2019). Design and development of coconut tree climbing robot. International Journal of Innovations in Engineering Research and Technology, 1-3.

[27] Arifin, K., Samosir, A. (2021). Design and simulation of coconut tree climbing tool for coconut farmers in Lombok Sangatta Bay, East Kutai. Journal of Industrial Engineering Management. https://doi.org/10.33536/jiem.specialedition.774

[28] Dhafir, M., Idkham, M., Lubis, A., Azrial, P. (2024). Work motion study on coconut tree climbing using a portable coconut climbing equipment. IOP Conference Series: Earth and Environmental Science, 1290(1): 012006. https://doi.org/10.1088/1755-1315/1290/1/012006

[29] Sethuramalingam, P., Shine, A. (2023). Ergonomic study in agricultural work by using ergonomic tool-REBA. International Research Journal of Modernization in Engineering Technology and Science. https://www.irjmets.com.

[30] Nag, P.K., Gite, L.P., Nag, P.K., Gite, L.P. (2020). Ergonomics application in design of farm tools and equipment. Human-Centered Agriculture: Ergonomics and Human Factors Applied, Springer, Singapore, pp. 301-331. https://doi.org/10.1007/978-981-15-7269-2_12

[31] Wibowo, A.H., Mawadati, A. (2021). The analysis of employees' work posture by using rapid entire body assessment (REBA) and rapid upper limb assessment (RULA). IOP Conference Series: Earth and Environmental Science, 704(1): 012022.

https://doi.org/10.1088/1755-1315/704/1/012022
[32] Tur, J.A., Bibiloni, M.D.M. (2019). Anthropometry, body composition and resting energy expenditure in human. Nutrients, 11(8): 1891. https://doi.org/10.3390/nu11081891
[33] Lund, A.M. (2001). Measuring usability with the use questionnaire 12. Usability Interface, 8(2): 3-6.

NOMENCLATURE

t	ton, a unit of weight equal to 2,000 pounds
ha	hectare, a metric unit of square measure
cm	centimeter, a metric unit of length
N	newton, the SI unit of force
kg	kilogram, the SI unit of mass
mm	millimeter, a metric unit of length
mm/min	millimeter per minute, the speed unit
Rp	rupiah, the basic monetary unit of Indonesia
F	force, strength or energy as an attribute of physical action or movement

Greek symbols

ε	epsilon, increase of length or original length