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INTELLIGENT SYSTEM FOR KNEE ERGONOMIC POSITION ANALYSIS DURING LIFTING LOADS

Vanessa C. ERAZO-CHAMORRO, Ricardo P. ARCINIEGA-ROCHA, Angel L. MALDONADO-MÉNDEZ, Paúl D. ROSERO-MONTALVO, Gyula SZABO

Abstract: *Adopting an ergonomic position during lifting loads in sports or work activities allows for reducing the negative impact produced by the wrong knee position during the development of different tasks. Movements in an erroneous way can cause muscle illness and lumbar injuries. The present electronic system acquires the data of the Smith bar and the position by means of accelerometer sensors. Using this system is implemented an intelligent device that allows recognizing if the activity/task is performed properly and gives the person feedback for improving the movement. As a result, after applying algorithms of machine learning to the system, it is determined also that more than 80% of workers are adopting dangerous positions during the tasks of lifting loads.*

Key words: *Automatic System, Knee Analysis, Safety work, Musculoskeletal Disorders, Knee position. Squats*

1. INTRODUCTION

The ergonomics is the interdisciplinary science focused on studying the physical limitations and abilities of the persons for each activity. In different environments where muscular work is required, in this sense ergonomics is the main part of assure the safer [1]. Altogether with biomechanics, these sciences studied the locomotion system of workers, which allows us to represent the musculoskeletal human system and to set up the training techniques for experts in work task activities [2]. The work weight lift activities and the squats sports have the same ergonomic postures to realise it properly as shown in Figure 1, relating the industrial and sports activities is possible to analyse different training techniques for muscles conditioning in high-performance sports [3]. The training techniques try to get the effectiveness in the expression of physical abilities for activities, for this reason, the principal objective of the biomechanical analysis collect data on specific technical details and gestures to find out possible failures in the execution of work activities related to lifting boxes or sport squats [4, 5].

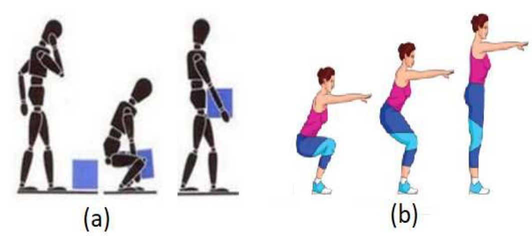

Fig. 1. (a) Ergonomic Industrial postures for lifting loads. (b) Ergonomic postures for squats.

Fig. 2. Femorotibial angle evaluation

In sports training exist some preferred exercises to strengthen the muscles in the legs one of them are the squats because allow improve the condition of the quadriceps and hamstrings. The muscles are activated when the knee is flexed from 90 to 100 degrees (angle formed between the femur and the tibia) [6]. In the case of work lift activities and the squat, if it is performed excessively, it will tendonitis or muscle strain, affecting the knee support. As result, it causes an illness known as sprains

The biomechanical model gives the mobility range of the knee shown in Fig 2 it permits identified wrong positions or techniques to reduce to be prone to suffering problems such ligaments or muscles distensions [7–9]. The proper posture support of feet should be spread in relation to the width of the shoulders and fingers facing forward to assure the correct biomechanical execution [10]. Besides, the movements of the knees must keep the direction tiptoe without exceeding it to forewarn internal rotation [11, 12]. In this context, the necessary steps for a good technique for the activity are (i) The head should always be level and never leaned forward or face the wrong way, (ii) Knees must be level and stretch out to shoulder level and (iii) With the legs straight as well as the abdominal tension, the lower back must fall down simultaneously [10].

Substantiated on the previous statements there are available biomechanical tools to simulate and get data on the body position from sensors to analyse these data through electronic devices and represent it in graphical data. This process is called embedded system (ES), it has variable applications due to its small size. The ES could be used in wearables textiles to collect biomechanical data to monitor the body of people. Intelligent textiles nowadays are used mostly by sportsmen to measure performance and collect data from the body to reduce injury possibilities [13–15]. Furthermore, machine learning techniques have the capacity to recognize forms, physical parameters to determine a specific class or group to try to find a solution task [16–18].

The main problem in the use of ES is the capacity of computational resources, which in that sense is needed a compulsory analysis of the data and classifies the most significant collected data from sensors to reduce memory usage and care for the battery life [19]. After managing the received data, the next step concerned the visualization to represent graphically and give users the possibility to analyse it [20, 21].

The present system works in the following way. An electronic embedded system for processing data from sensors and represents the biomechanics of the knee during the activities. In the next step, the results of the system are presented on the computer for evaluation and training of people whit sonorous feedback to improve the performed task.

The rest of this work is structured as follows: Section 2 presents Related works. Section 3 shows, the design of the system and its functioning. Section 4 indicates data analysis and the results. Section 5 presents the conclusions. Finally, Section 6 Acknowledgment and future work

2. RELATED WORKS

In order to amelioration some works were made, in chronological form, they are presented to the most relevant in the different years:

In 2011, Eitner, J D [22] ; presents a "Kinematic and Kinetic Analysis of the Squat with and Without Knee Wraps" where is concluded the use of knee wraps has not influenced in squat performs.

In 2014, S. A. Horan [23] presents, "Lower-limb kinematics of single-leg squat performance in young adults" to explain the correct performance of squats. Then during 2016 A. Raısanen [24] presents, "Single-Leg Squat as a Tool to Evaluate Young Athletes" for evaluating the good or bad performance of squats.

In 2020, MegumiOta presents [25], "Verification of reliability and validity of motion analysis systems during bilateral squat using human pose tracking algorithm" using images during bilateral squat recorded with digital video camera, and the joint angles were measured.

Given the works cited above, the systems are focused on obtaining data from recorder images and evaluating in the future without feedback from the person who is making the activity. In this sense, the proposed system implements an ES in charge to evaluate in real-time with the capacity to give a sonorous alarm to inform the user of the incorrect postural position of the Knee during the task.

3. MATERIALS AND METHODS

This section presents on one hand the embedded system design. On the other hand, it shows the implementation and training for workers.

3.1 Embedded System Design

The complete electronic system is structured based on IEEE 29148 standard [26] which specified the necessary requirements for a correct function and training system Table 1 shows the functionality and user requirements.

The requirements give the functioning process to develop the correct measure task by the device [27, 28], Figure 3 indicates the process flow: it starts when the worker makes the exercise, then filtering the data by an electronic system and its training is done by machine learning to reduce the received data from sensors, after the filtering process the measured data is sent by wireless to a computer for a graphical representation and evaluation by experts, at the same time if the ES determined a wrong position of the knee sent a sonorous alarm to the person who is doing the exercise for correction of the position.

Based on the biomechanical theoretical statements for the knee [29, 30] during the system training and under biomechanical experts the ES was trained and calibrated for a correct response while the measures are taken from the angles and knee position to determine the possible dangerous positions, after the training step the system learned by artificial intelligence the necessary data for future response.

3.2 Implementation and training for workers.

The implemented system fulfilled the requirements of standards and users following the designed and proven systematic steps to determine the correct posture [31, 32]. The system harvests the data from the sensor at the Knee to know if the knee exceeds tiptoe to determine if exists any deviation during the activities the postures are shown in Figure 4.

Table 1

System Requirements

System Requirements (SHr)					
#	Requirements	Priority			Relationship
		High	Medium	Low	
SHr1	Ease of system use	X			SHr3
SHr2	Error bad posture system alarm	X			SHr6
SHr3	The system must has a visualization interface	X			SHr1
SHr4	The data analysis must be in real time	X			SHr8
SHr5	The system must has a light weight	X			SHr1
SHr6	The system must measure the knee angle	X			SHr2
SHr7	The system must measure deviation angle	X			SHr1
SHr8	The load computational must be less as possible		X		SHr4

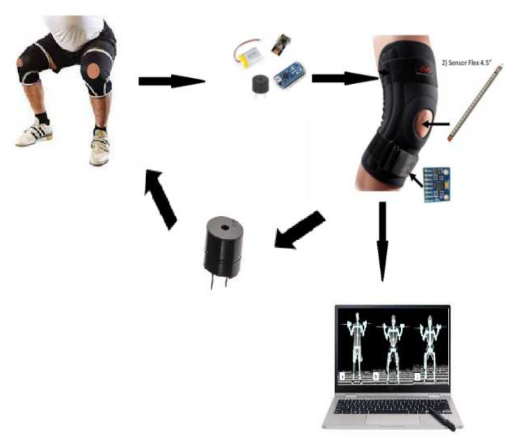

Fig. 3. Embedded System Functioning.

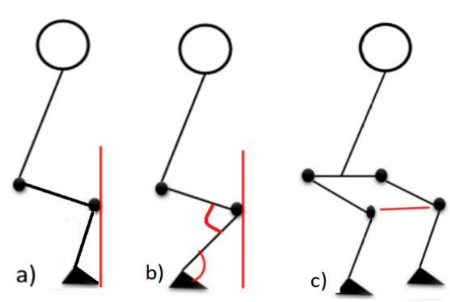

Fig. 4. Embedded System Functioning.

The data is classified into five different causes to determine the knee position and determine the need for the alarm to correct the posture persons[33–35].

The first measure is the femorotibial angle shown in part b) of Figure 4, for the proposed is used of a flexible resistive sensor that allows determining the knee angle using equation 1 and then interpolating the angle data by the datasheet of the sensor, the ES assign the value 5 at the end of the data transmission to identify it.

$$v_{out} = v_{in}\frac{R_1}{R_1+R_2} \quad (1)$$

Where:

v_{out}= Resultant voltage

v_{in}= Initial voltage

$R_1 R_2$=Internal circuit resistors.

Through the 3D sensor, the knee position is determined by the different postures, in part a) of Figure 4 shows the correct knee position when the sensor receives the data in this range, the ES assign the value 1 at the end of the data transmission to identify it. In addition, the ES assign the value 2 for data from abduction and 3 to these data from adduction shown in part c) of Figure 4.

Finally, the ES assign the value 4 to data indicating the knee surpassed the tiptoe shown in part a) of Figure 4, in all wrong positions, the sonorous alarm turns on to indicate the person the need to correct the ergonomic position.

4. RESULTS

The data analysis results, including the system execution evaluations, are presented in this part, these data were collected father the calibration phase [36].

Table 2 shows the analysed data received and processed by ES according to a test with 385 participants where each one performed 5 attempts with the purpose to collect data.

The distribution data presented in Figure 5 show the attempts where the workers have a good ergonomic posture where the system classifies these data with the value 1 at the end of the transmission data line.

Table 2

Statistical data of the test.

INDEX	MIN	MAX	MEAN	SD	RANGE
1	52,09	86,3	74,28	7,7367603	34,21
2	68,58	84,32	74,2226733	7,59470829	15,74
3	-33,6	-8,08	-11,5725686	5,97991188	25,52
4	-10,06	89,57	68,4706948	14,2738388	99,63
5	-27	137	73,5248756	36,9025897	164

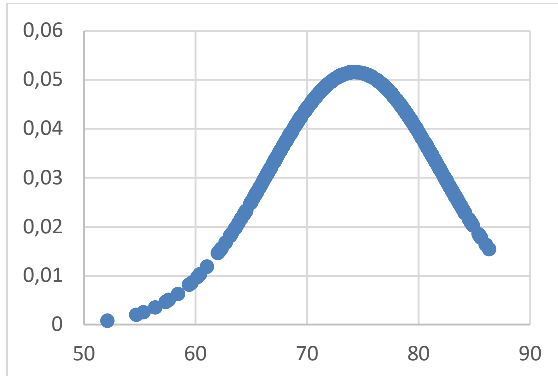

Fig. 5. Data distribution of the correct posture.

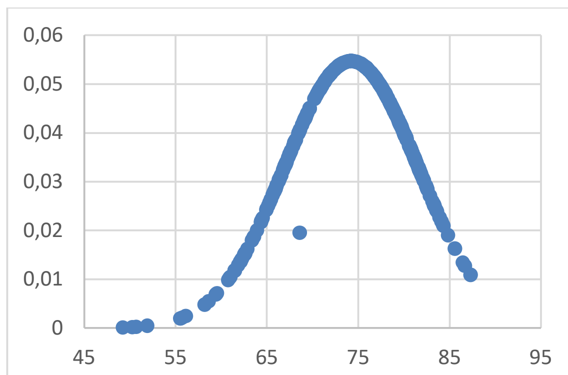

Fig. 6. Data distribution of the abduction failure posture.

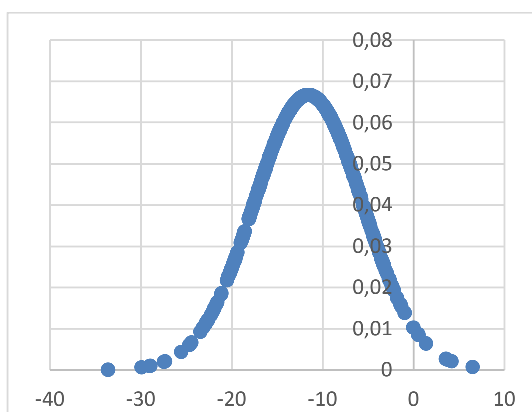

Fig. 7. Data distribution of the adduction failure posture

The distribution data presented in Figure 6 show the attempts where the workers have abduction failure posture where the system classifies these data with the value 2 at the end of the transmission data line.

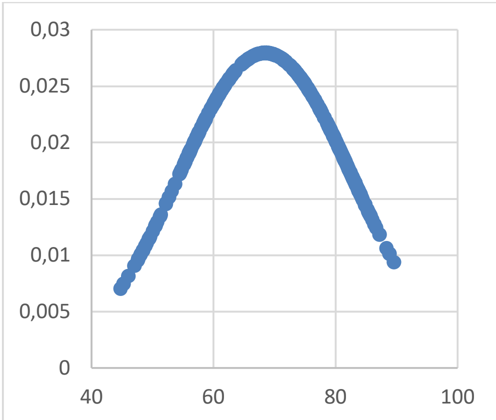

Fig. 8. Data distribution of the knee surpasses tiptoe.

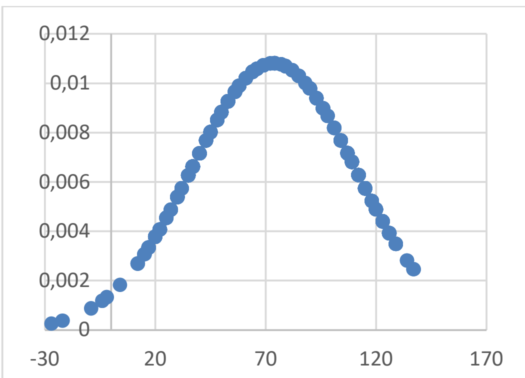

Fig. 9. Data distribution of the femorotibial angle failure posture.

The distribution data presented in Figure 7 show the attempts where the workers have adduction failure posture where the system classifies these data with the value 3 at the end of the transmission data line.

The distribution data presented in Figure 8 show the attempts where the workers have knee surpasses tiptoe, where the system classifies these data with the value 4 at the end of the transmission data line. The distribution data presented in Figure 9 show the attempts where the workers have femorotibial angle failure posture. where the system classifies these data with the value 9 at the end of the transmission data line.

5. CONCLUSION

Nowadays the principal concern in the industry is to save resources and keep safe the workers to increase their incomes [37, 38], in this sense detecting the possible causes of a future illness or possible failure in the ergonomic position during the task is the best way to achieve the objective, whit this objective in mind previous works tried to analyse the behaviour worker based on the observation [39], and the identification of the work risk for activities in case of lifting loads [40-42].

This paper is substantiated by previous studies for demonstrating the viability of lifting loads detection using wearable sensors, based on automation advances after being processed the database is determined that 19,6% of workers keep a correct ergonomic posture during the activities as is shown in the Figure 10. In the case of the non-correctly ergonomic position, the workers receive a sonorous alarm indicating the need to improve the posture to change the behaviour of the person during the task, these cases represent 80.4% of the data sensed, in addition, this value is divided in for different cases according to the different failure be represented in computer and help to ergonomic managers indicate the failure, like it is shown in Figure 11.

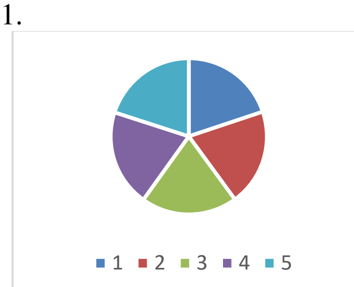

Fig. 10. Percentage representation of the collected data.

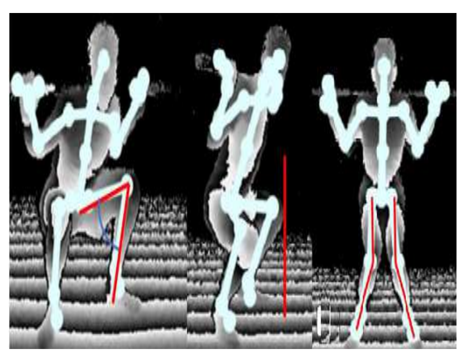

Fig. 11. Data visualization.

In future work, an analysis-oriented artificial vision identification and recognition of the posture to develop the same activity and a comparison of the results of knee positions to orient the workers and improve the posture during the industrial activities could be proposed. On the other hand, this device could be applied and adapted to measure and recognise the hand and wrist position to avoid non-adequate ergonomic postures in the industrial task during the activities involving hand tools uses.

6. ACKNOWLEDGMENT

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7. REFERENCES

[1] Crossley, K. M., Zhang, W. J., Schache, A. G., Bryant, A., Cowan, S. M., *Performance on the single-leg squat task indicates hip abductor muscle function*, Am. J. Sports Med., 39(4), pp. 866–873, doi: 10.1177/0363546510395456, 2011.

[2] Nagano, Y., Ida, H., Akai, M., Fukubayashi, T., *Gender differences in knee kinematics and muscle activity during single limb drop landing*, Knee, 14(3), pp. 218–223, doi: 10.1016/J.KNEE.2006.11.008, 2007.

[3] Garhammer, J., *Weight Lifting and Training*, Biomech. Sport, pp. 169–211, doi: 10.4324/9781003068549-5, 2020.

[4] Boissoneault, J. Sevel, L., Letzen, J. Robinson, M. Staud, R., *Biomarkers for Musculoskeletal Pain Conditions: Use of Brain Imaging and Machine Learning*, Curr. Rheumatol. Rep., 19(1), pp. 1–9, doi: 10.1007/S11926-017-0629-9/TABLES/2, 2017.

[5] Poulsen, D. R., James, C. R., *Concurrent validity and reliability of clinical evaluation of the single leg squat*, Physiotherapy theory and practice, 27(8), pp. 586-594, 2011.

[6] Levinger, P., Gilleard, W., Coleman, C., *Femoral medial deviation angle during a one-leg squat test in individuals with patellofemoral pain syndrome,* Phys. Ther. Sport, 8(4), pp. 163–168, doi: 10.1016/J.PTSP.2007.03.003, 2007.

[7] Weeks, B. K., Carty, C. P., Horan, S. A., *Effect of sex and fatigue on single leg squat kinematics in healthy young adults*, BMC Musculoskelet. Disord., 16(1), pp. 1–9, doi: 10.1186/S12891-015-0739-3/FIGURES/2, 2015.

[8] Waters, T. R., Putz-Anderson, V., Garg, A., Fine, L. J., *Revised NIOSH equation for the design and evaluation of manual lifting tasks*, Ergonomics,36(7), pp. 749–776, doi: 10.1080/00140139308967940, 1993.

[9] Occhipinti, E. Colombini, D., *A toolkit for the analysis of biomechanical overload and prevention of WMSDs: Criteria, procedures and tool selection in a step-by-step approach*, Int. J. Ind. Ergon., 52, pp. 18–28, doi: 10.1016/J.ERGON.2015.08.001, 2016.

[10] Liu, T., Inoue, Y., Shibata, K., Shiojima, K., *Three-dimensional gait analysis system with mobile force plates and motion sensors*, URAI 2011 - 2011 8th Int. Conf. Ubiquitous Robot. Ambient Intell., pp. 107–110, doi: 10.1109/URAI.2011.6145942, 2011.

[11] Nakagawa, T. H., Moriya, E. T. U., MacIel, C. D., Serrão, F. V., *Trunk, pelvis, hip, and knee kinematics, hip strength, and gluteal muscle activation during a single-leg squat in males and females with and without patellofemoral pain syndrome*, J. Orthop. Sports Phys. Ther., 42(6), pp. 491–501, doi: 10.2519/jospt.2012.3987, 2012.

[12] Chaffin, D. B., *Occupational biomechanics—a basis for workplace design to prevent musculoskeletal injuries*, Ergonomics, 30(2), pp. 321-329, 1987.

[13] Kianifar, R., Lee, A., Raina, S., Kulić, D. *Automated assessment of dynamic knee valgus and risk of knee injury during the single leg squat*, IEEE Journal of Translational Engineering in Health and Medicine, 5, pp. 1-13, 2017.

[14] Szabo, G., *ErgoCapture—A Motion Capture Based Ergonomics Risk Assessment Tool*, Advances in Physical Ergonomics and Human Factors: Part II, pp. 313–321, 2018.

[15] Szabó, G. Németh, E., *Development an Office Ergonomic Risk Checklist: Composite Office Ergonomic Risk Assessment (CERA Office)*, Adv. Intell. Syst. Comput., 819, pp. 590–597, doi: 10.1007/978-3-319-96089-

0_64, 2018.

[16] Rosero-Garcia, J. F., Llanes-Cedeño, E. A., Arciniega-Rocha, R. P., López-Villada, J., *Analysis of Prediction and Clustering of Electricity Consumption in the Province of Imbabura-Ecuador for the Planning of Energy Resources*, Lect. Notes Networks Syst., 284, pp. 1073–1084, doi: 10.1007/978-3-030-80126-7_75, 2021.

[17] Rosero-Montalvo, P. D., López-Batista, V. F., Peluffo-Ordóñez, D. H., Erazo-Chamorro, V. C., Arciniega-Rocha, R. P., *Multivariate Approach to Alcohol Detection in Drivers by Sensors and Artificial Vision*, International Work-Conference on the Interplay Between Natural and Artificial Computation, pp. 234–243, doi: 10.1007/978-3-030-19651-6_23, 2019.

[18] Toapanta-Lema, A., Gallegos, W., Rubio-Aguilar, J., Llanes-Cedeño, E., Carrascal-García, J., García-López, L., Rosero-Montalvo, P. D., *Regression models comparison for efficiency in electricity consumption in ecuadorian schools: a case of study*, International Conference on Applied Technologies, pp. 363-371, Springer, Cham, 2019.

[19] Rosero-Montalvo, P., Peluffo-Ordónez, D. H., Umaquinga, A., Anaya, A., Serrano, J., Rosero, E., ..., Suaréz, L., *Prototype reduction algorithms comparison in nearest neighbor classification for sensor data: Empirical study*, 2017 IEEE Second Ecuador Technical Chapters Meeting (ETCM), pp. 1-5, IEEE, 2017.

[20] Rosero-Montalvo, P. D., Umaquinga-Criollo, A. C., Flores, S., Suarez, L., Pijal, J., Ponce-Guevara, K. L., ..., Moncayo, K., *Neighborhood criterion analysis for prototype selection applied in WSN data*, 2017 International Conference on Information Systems and Computer Science (INCISCOS), pp. 128-132, IEEE, 2017.

[21] Rosero-Montalvo, P., Jaramillo, D., Flores, S., Peluffo, D., Alvear, V., Lopez, M., *Human sit down position detection using data classification and dimensionality reduction*, Advances in Science, Technology and Engineering Systems Journal, 2(3), pp. 749-754, 2017.

[22] Eitner, J. D., LeFavi, R. G., Riemann, B. L., *Kinematic and kinetic analysis of the squat with and without knee wraps*, The Journal of Strength & Conditioning Research, 25, p. S41, 2011.

[23] Horan, S. A., Watson, S. L., Carty, C. P., Sartori, M., Weeks, B. K., *Lower-limb kinematics of single-leg squat performance in young adults*, Physiotherapy Canada, 66(3), pp. 228-233, 2014.

[24] Räisänen, A., Pasanen, K., Krosshaug, T., Avela, J., Perttunen, J., Parkkari, J., *Single-Leg squat as a tool to evaluate young athletes' frontal plane knee control,* Clinical Journal of Sport Medicine, 26(6), pp. 478-482, 2016.

[25] Ota, M., Tateuchi, H., Hashiguchi, T., Kato, T., Ogino, Y., Yamagata, M., Ichihashi, N., *Verification of reliability and validity of motion analysis systems during bilateral squat using human pose tracking algorithm*, Gait & posture, 80, pp. 62-67, 2020.

[26] *IEEE/ ISO/ IEC 29148 - 2011. Systems and software engineering - Life cycle processes - Requirements engineering*, https://standards.ieee.org/ieee/29148/5289/.

[27] Forastieri, V., *Improving health in the workplace: ILO's framework for action*, Geneva, International Labour Organization, 4, 2014.

[28] CCOHS, W*ork-related Musculoskeletal Disorders (WMSDs): OSH Answers*, https://www.ccohs.ca/oshanswers/diseases/rmirsi.html.

[29] Madeti, B. K., Chalamalasetti, S. R., Pragada, B., *Biomechanics of knee joint—A review,* Frontiers of Mechanical Engineering, 10(2), pp. 176-186, 2015.

[30] Escamilla, R. F., *Knee biomechanics of the dynamic squat exercise*, Medicine & science in sports & exercise, 33(1), pp. 127-141, 2001.

[31] *EU-OSHA Glossaries. Musculoskeletal disorders*, https://osha.europa.eu/en/tools-and-resources/glossaries

[32] CCOHS, *Working in a Standing Position - Basic Information*, https://www.ccohs.ca/oshanswers/ergonomics/standing/standing_basic.html.

[33] Chiou, P., Borg-Stein, J., *Cumulative trauma disorders*, DeLisa's Physical

Medicine and Rehabilitation: Principles and Practice: Fifth Edition, 1–2, CRC Press, pp. 923–936, 2012.
[34] Marras, W. S., *Basic biomechanics and workstation design*, Handbook of human factors and ergonomics, 3, pp. 340-370, 2006.
[35] M Castro, M., Druschel, P., Kermarrec, A. M., & Rowstron, A., *One ring to rule them all: Service discovery and binding in structured peer-to-peer overlay networks*, Proceedings of the 10th workshop on ACM SIGOPS European workshop, pp. 140-145, 2002.
[36] Llanes-Cedeño, E. A., Meza-Cartagena, J. F., Gallegos Eras, W., Rubio Aguiar, R. J., Arciniega-Rocha, R. P., Erazo-Chamorro, V. C., ..., Toapanta-Lema, A., *Analysis and study of energy efficiency in the electric system of the millennium education schools "SUMAK YACHANA WASI of Imbabura Province in Ecuador*, International Journal of Advanced Science andTechnology, 29(7), pp. 14040-14051, 2020.
[37] Erazo-Chamorro, V. C., M*áquina peladora rotadora de maní tostado para la industria artesanal*, http://repositorio.utn.edu.ec/handle/123456789/3755.
[38] Arciniega-Rocha, R. P., *Máquina Tostadora Rotatoria De Maní Para La Industria Artesanal Con Sistema Semiautomático*, http://repositorio.utn.edu.ec/handle/123456789/3743.
[39] Ciriello, V. M., T*he effects of box size, frequency and extended horizontal reach on maximum acceptable weights of lifting*, International Journal of Industrial Ergonomics, 32(2), pp. 115-120, 2003.
[40] Marler, T., Knake, L., Johnson, R., *Optimization-based posture prediction for analysis of box lifting tasks*, International Conference on Digital Human Modeling, pp. 151-160, Springer, Berlin, Heidelberg, 2011.
[41] Greene, R. L., Hu, Y. H., Difranco, N., Wang, X., Lu, M. L., Bao, S., ... , Radwin, R. G., *Predicting sagittal plane lifting postures from image bounding box dimensions,* Human factors, 61(1), pp. 64-77, 2019.
[42] Jorge, J. G., Dionisio, V. C., *Biomechanical analysis during single-leg squat in individuals with knee osteoarthritis*, The Knee, 28, pp. 362-370, 2021.

Sistem inteligent pentru analiza poziției ergonomice a genunchilor în timpul ridicărilor

Rezumat: Adoptarea unei poziții ergonomice în timpul ridicării sarcinilor în activități sportive sau de muncă permite reducerea impactului negativ produs de poziția greșită a genunchiului în timpul desfășurării diferitelor sarcini. Mișcările incorecte pot provoca afecțiuni musculare și leziuni lombare. Actualul sistem electronic achiziționează datele barei Smith și poziția prin intermediul senzorilor accelerometrului. Folosind acest sistem este implementat un dispozitiv inteligent care permite evaluarea efectuării corecte a activității/sarcinii și oferă persoanei feedback pentru îmbunătățirea mișcării. Ca urmare, după aplicarea algoritmilor de învățare automată în sistem, s-a determinat, de asemenea, că peste 80% dintre lucrători adoptă poziții periculoase (vicioase) în timpul sarcinilor de ridicare a sarcinilor.

Vanessa C. ERAZO-CHAMORRO, Óbuda University, Donát Bánki Faculty of Mechanical and Safety Engineering, erazo.vanessa@uni-obuda.hu, +36 204398956, Népszínhaz u.8, Budapest, Hungary.

Ricardo P. ARCINIEGA-ROCHA, Óbuda University, Donát Bánki Faculty of Mechanical and Safety Engineering, arciniega.ricardo@uni-obuda.hu, +36 203920474, Népszínhaz u.8, Budapest, Hungary.

Angel L. MALDONADO-MÉNDEZ, Universidad Técnica del Norte, Faculty of Applied Engineering, rickypato14@gmail.com, +593 969432370, Ibarra, Ecuador.

Paúl D. ROSERO-MONTALVO, IT University of Copenhagen, Computer Science Department, paur@itu.dk, +4572185000, Rued Langgaards Vej 7 Dk-2300, Copenhagen, Denmark.

Gyula SZABO, PhD, Eur. Erg. Óbuda University, Donát Bánki Faculty of Mechanical and Safety Engineering, szabo.gyula@uni-obuda.hu, +36 203349199, Népszínhaz u.8, Budapest, Hungary