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VALIDATION OF THE PMHWLmax ETSIMATION MODEL FOR MANUAL HANDLING WEIGHT LIMITS, BASED ON ANTHROPOMETRICS AND SPECIFIC LOAD AND TASK REQUIREMEMENTS

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TECHNICAL NOTE

Abstract The aim of this study was the validation of the published method for the estimation of the personal maximum manual handling weight limit (PMHWLmax) which is based on the personal body weight, as a reference to general population percentiles anthropometrics. For this purpose, an experiment was designed, were a repetitive process of transferring progressively increasing loads, was performed, with the aim of identifying through EMG recording of the erector spinae muscle, the load that brings about the first distinct quantity change in muscle activation and fatigue, compared to the preceding trials and afterwards the matching of the specific load value with the body weight of the participant.

Keywords: ergonomics; occupational health and safety; WMSDs; electromyography; anthropometrics.

1. INTRODUCTION

In a previous publication [1], a model table was designed, according to which, a safe personal maximum manual handling weight limit ($PMHWL_{max}$) can be determined, for each person, based on the anthropometric population data of weight, height, BMI and the corresponding distributions (percentiles), in combination with the weight handling elements, resulting from the purpose, the strategy of the management-handling of the load and the capacity of the worker. The aim of this study was the validation of the method for the estimation of the personal maximum manual handling weight limit (PMHWLmax).

2. MATERIALS AND METHODS

2.1. Subjects

Fifteen (15) healthy young adult male individuals aged 20-25 years were selected randomly, (Table 1).

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Table 1. Sample descriptive characteristics.

	N	Min	Max	Mean	SD
BW	15	64	114	84,47	14,618
BMI	15	20	37	28,34	5,343
HEIGHT	15	1,67	1,91	1,7547	,05705
Valid N (listwise)	15				

The experiment and the measurements carried out at the Laboratory of Biomechanics and Ergonomics, @ErgoMechLab – DPESS / Department of Physical Education and Sport Science, of University of Thessaly. The subjects were given an oral explanation of the testing procedures. Additionally, they were informed about the correct way to lift and position an object from/to the ground, as well as to hold it during the transfer and did familiarization trials before the start of the experiment. They were free from musculoskeletal problems and had no pathological condition. All the participants were occasionally physically active. Regular or high-level athletes were excluded.

Each examinee would have to lift a cubic box (crate 40X40X40cm) with a starting weight of 21kg from the ground and carry it 15m, turn and return to the starting point (total transfer distance 30m) and deposit it on the ground. Every 5 minutes of rest in a sitting position, he repeated the trials, adding +1kg each time, until he carried 30kg (a total of 10 trials).

The detection of muscle activation was done through EMG recording of the erector spinae muscle, bilaterally, during each trial.

2.2. Method

A wireless EMG system (Ultium EMG, 8-ch, Noraxon™ U.S.A. Inc.) were used to examine changes in muscle activation in the erector spinae muscle, bilaterally. Two sEMG bipolar electrodes were placed bilaterally at 2 finger width lateral from the proc. spinae of L1, in accordance with SENIAM guidelines [2]. The EMG signal was then processed and smoothened by band-pass filtering at 10-400 Hz (4^{th} order Butterworth filter). A Fast-Fourier Transform (FFT) window analysis was applied to determine the cutoff frequencies. Further, the FFT was also used to obtain the mean power frequency (MPF). The signal amplitude of sEMG was rectified and calculated as root mean square (RMS) values. Subsequently, the MPF and RMS amplitude was used for statistical analysis.

Muscle fatigue of the selected muscles was estimated and calculated as the percentage difference in mean RMS referring to the half transfer route distance (15m) upon initiation of the ambulation (after lifting) and the mean RMS of the return transfer route of the ambulation (15m), (before placed down). Thus, the RMS amplitude growth rate (RMS%) and the frequency drop rate (MPF%) of the selected muscles, were calculated during each trial. The MPF% is used to confirm the presence of peripheral muscle fatigue in erector spinae, as changes in EMG frequency domain variables are strongly associated with muscle fiber conduction velocity (MFCV) [3], which in turn has been found to be related to changes in intracellular pH, and consequently peripheral fatigue [4].

Based on the analysis of each trial for each examinee, the RMS% and MPF% values were calculated and the trial in which there was a distinctly significant change in those values, compared to the previous trials, was identified. The $load_{(Kg)}$ corresponding to this trial was marked as dangerous (named, redFlag), so from then on, the specific person is overloaded. Thus, it is defined as the max safe load, the immediately preceding $load_{(Kg)}$ (named, greenFlag), (Table 2). After collecting the greenFlag load for each examinee, the load matched with his body weight. This match correlated with the estimated load values which provides the PMHWLmax method and it is based on population anthropometrics (corresponding distributions, percentiles for Body weight), to validate the method.

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3. STATISTICAL ANALYSIS

To examine the validity of the PMHWLmax method, a Pearson correlation coefficient was performed to mark the correlation level between the maximum safe load identified for everyone through the experiment, with the maximum safe load given by the PMHWLmax method based on their body weight. The primary data was analyzed in MATLAB® (R2015b, Mathworks Inc., Natick, MA, USA) and remaining data was analyzed using SPSS ver. 27.0 statistical program for Windows (SPSS Software, IBM Inc., Chicago, IL, USA). The level of significance was set at $p < 0.05$, with a confidence level (C.I.) set at 95%.

4. RESULTS

4.1. Myoelectric Activity and Peripheral Fatigue

All participants showed a progressive increase in fatigue proportional to the increase in load between trials. Table 2, shows the identification of the max safely transferred load (corresponding to greenFlag point) before the appearance of a distinct RMS% increase and MPF% decrease rate (redFlag), per person (Figure 1).

Table 2. Estimation of the max safely transferred load (corresponding to greenFlag point) before the appearance of a distinct RMS% increase and MPF% decrease rate (redFlag), per person.

Transferred load in Kg

		21	22	23	24	25	26	27	28	29	30	BW
RMS%	1	17	20	19	23	33	40	41	50	57	70	75
	2	15	18	35	37	44	49	56	68	73	80	68
	3	19	24	29	34	38	42	63	67	71	70	84
	4	27	36	40	44	65	64	71	77	81	79	77
	5	19	25	27	36	39	56	55	60	67	66	92
	6	29	40	40	58	56	66	71	75	74	80	70
	7	16	21	20	24	29	31	48	51	57	62	99
	8	18	20	25	30	30	43	47	53	66	75	69
	9	20	23	29	35	44	48	54	77	76	77	103
	10	20	24	33	37	42	46	59	63	67	76	94
	11	22	34	38	44	50	56	67	71	77	82	64
	12	14	15	19	22	27	26	29	37	51	59	114
	13	19	25	28	33	47	52	55	64	68	67	92
	14	16	19	24	23	26	39	36	44	52	59	89
	15	24	33	38	51	57	56	62	69	75	78	77

Transferred load in Kg

		21	22	23	24	25	26	27	28	29	30	BW
MPF%	1	-24	-22	-28	-30	-49	-48	-52	-56	-60	-59	75
	2	-35	-41	-56	-58	-62	-64	-63	-67	-64	-70	68
	3	-20	-25	-27	-35	-39	-43	-60	-57	-63	-68	84
	4	-30	-36	-44	-47	-61	-64	-65	-71	-77	-80	77
	5	-27	-36	-40	-47	-50	-66	-69	-71	-74	-72	92
	6	-27	-33	-36	-48	-51	-56	-62	-71	-77	-81	70
	7	-21	-28	-34	-33	-37	-43	-57	-55	-64	-69	99
	8	-29	-37	-41	-48	-52	-63	-68	-74	-79	-84	69
	9	-17	-16	-19	-20	-27	-30	-31	-45	-53	-64	103
	10	-22	-20	-26	-27	-36	-38	-52	-51	-60	-64	94
	11	-30	-46	-49	-54	-57	-66	-71	-75	-79	-86	64
	12	-20	-22	-25	-31	-40	-48	-51	-59	-70	-74	114
	13	-19	-22	-27	-27	-39	-44	-46	-53	-61	-70	92
	14	-20	-24	-31	-36	-45	-57	-59	-64	-67	-75	89
	15	-24	-30	-36	-48	-46	-53	-59	-66	-71	-77	77

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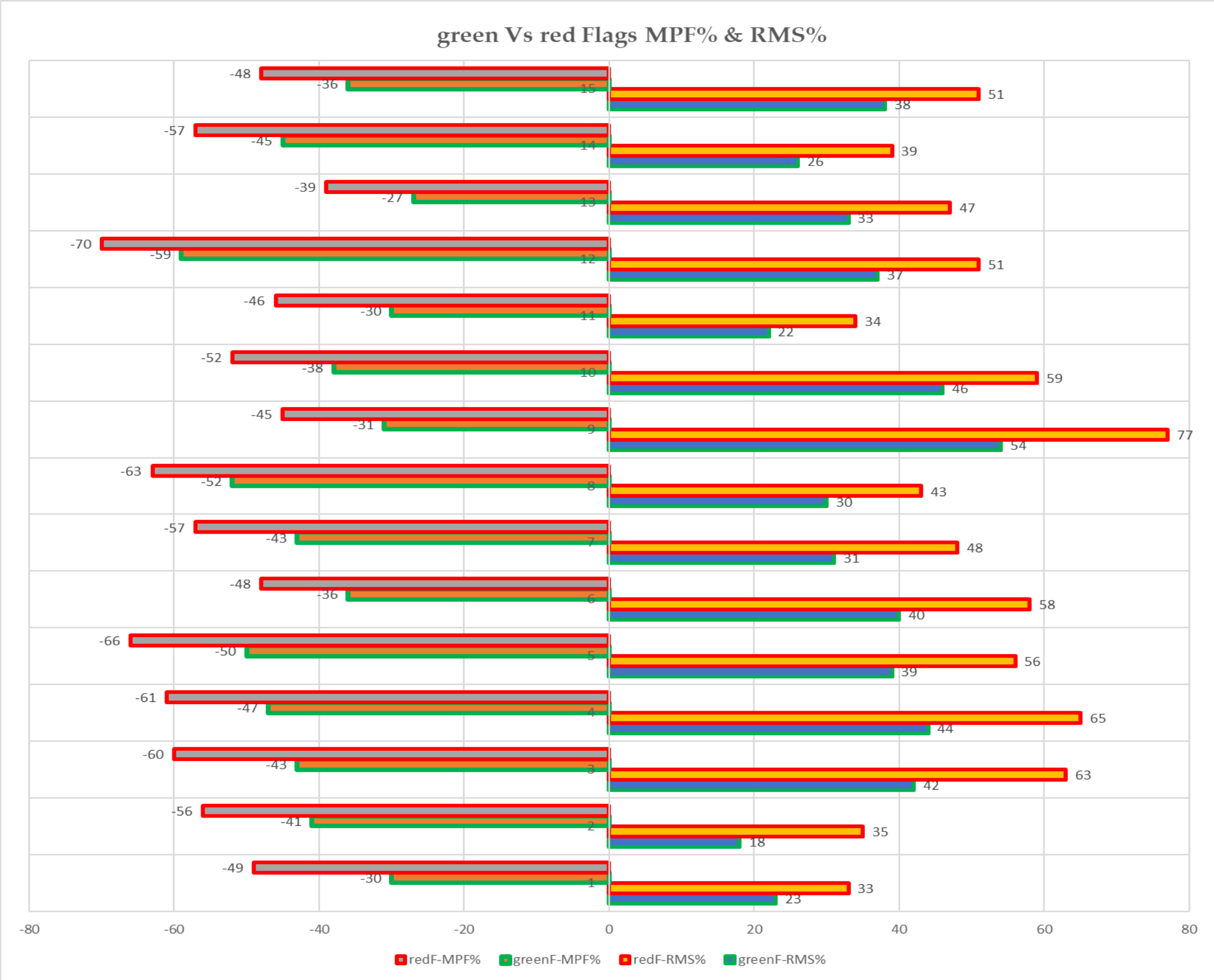

Figure 1. The MPF% drop rate and RMS% increase rate, at the green Vs red Flag point, per person.

4.2. Correlations

The correspondence between the greenFlag estimated load$_{Kg}$ and the PMHWLmax model estimated load$_{Kg}$, per person, (Figure 2), provided a high correlation value of ,855 significant at the 0.01 level (2-tailed), (Table 3).

Table 3. Correlation between the greenFlag estimated loadKg and the PMHWLmax model estimated loadKg, per person.

Correlations		greenFlag loads	PMHWL$_{max}$ model loads
greenFlag loads	Pearson Correlation	1	**,855****
	Sig. (2-tailed)		**<,001**
	N	15	15
PMHWL$_{max}$ model loads	Pearson Correlation	,855**	1
	Sig. (2-tailed)	<,001	
	N	15	15
**. Correlation is significant at the 0.01 level (2-tailed).			

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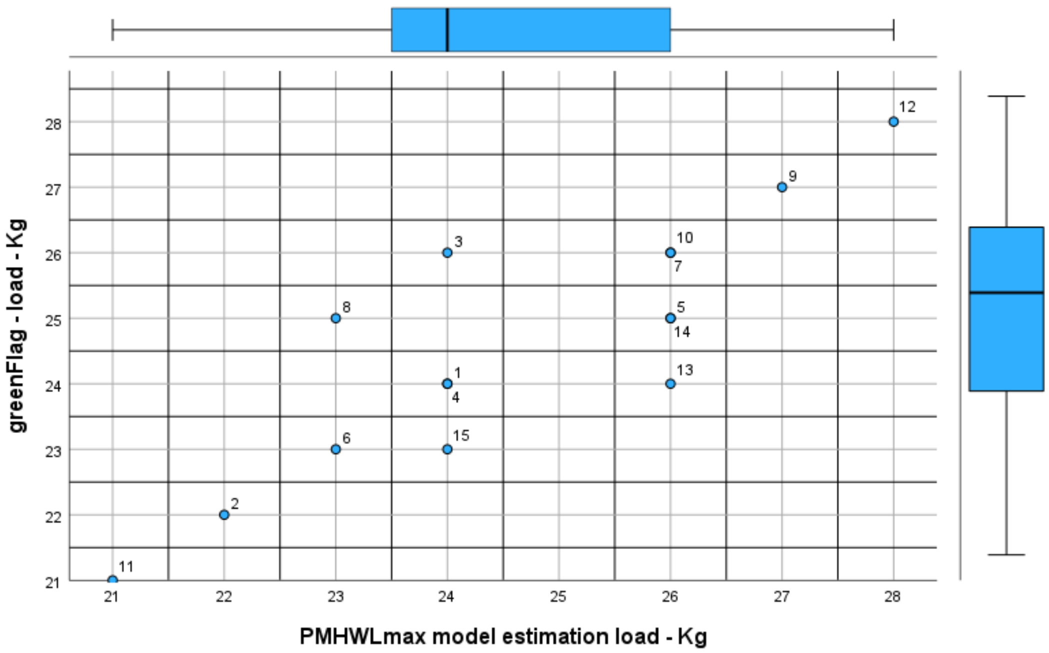

Figure 2. Correspondence between the greenFlag estimated load$_{Kg}$ and the PMHWLmax model estimated load$_{Kg}$, per person (N=15).

5. CONCLUSION

Based on the results of the experiment performed for the validity of the model PMHWLmax for the estimation for manual handling weight limits, which uses anthropometrics and specific load and task requirements, a high correlation (.855 p< ,001) between the calculated safe load values was shown, confirming through the quantitative approach of muscle loading and strain, the model PMHWLmax which is based on anthropometry.

References

[1] Tsaklis, P. V., 2025, Manual handling weight limits, based on anthropometrics and specific load and task requirements, *IETI Transactions on Ergonomics and Safety*, 9(2), pp. 9–13.

[2] Criswell, E., 2011, *Cram's introduction to surface electromyography* (2nd ed.), Jones and Bartlett, Sudbury, MA.

[3] Boccia, G., Dardanello, D., Tarperi, C., Rosso, V., Festa, L., La Torre, A., Pellegrini, B., Schena, F., and Rainoldi, A., 2017, Decrease of muscle fiber conduction velocity correlates with strength loss after an endurance run, *Physiological Measurement*, 38(2), pp. 233–240.

[4] Beretta-Piccoli, M., D'Antona, G., Barbero, M., Fisher, B., Dieli-Conwright, C. M., Clijsen, R., and Cescon, C., 2015, Evaluation of central and peripheral fatigue in the quadriceps using fractal dimension and conduction velocity in young females, *PLOS ONE*, 10(4), e0123921.