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Slope effect on pushing forces

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Abstract: In some occupations pushing forces are frequent when performed on horizontal ground and are standardized (ISO 2002). In special cases employees are obliged to grow container on slopes and the strains are poorly investigated. The objective of this work is to measure forces required to push garbage container on horizontal and inclined at 0, 4, 11 and 16 % grounds. Sudden and significant increases in heart rate reflect the possible risk of heart overload in long displacements. This study proposes realistic limits and provides a simple and protective tool for a group of employees without distinction of age or gender. These limits can even be reduced to a quasi-linear model where push 200 kg is the maximum for 0% slope and 60 kg for 10% slope.

Keywords: Pushing force, Slope, limits

1. Introduction

In some occupations pushing forces are frequent when performed on horizontal ground and are standardized [2]. In special cases employees are obliged to grow container on slopes. These strains are poorly investigated. The objective of this work is to measure forces required to push garbage container on horizontal and inclined at 0, 4, 11 and 16 % grounds. Introduction

2. Method

The 16 employees (4 women and 12 men) who volunteered in the study had no known pathology. They were accustumed to the task which was a regular component of their every day activity. Their average age was 47.2 (sd = 9.2) years. Pushing strength was analysed by its initial (Finit) and sustained (Fsust) component. This field study was performed outside on concrete ways with 4 slopes of 0, 4, 11 and 16 %. A garbage container of 500 l weighing 55 kg was used with additional loads between 60 and 240 kg. Container displacements were between 11 and 15 m. The first meter was considered the initial phase and the following 10 meters were divided into 2 successive 5 m zones. A keypad connected to the computer permitted to time precisely the path and calculate the speed of moving containers. The loads were placed in the container so that employees had no indication about the actual weight. The order of the 16 conditions (loadxslope) was at random. The heart rate (HR) in beats per minute (bpm) was recorded using a Polar 810 with a counting time of 5 s. HR data was expressed as its peak value (Hrpeak) for each condition. At the end of each test subject sits at least 5 minutes, during which the general strain of the pushing condition was assessed on a RPE scale [1].

3. Results

- The peak HR cost (dHR = HRpeak – HRrest) is related to slope, load and gender:

$$dHR = 1.66\ slope + 0.065\ load + 23\ gender$$

relationship 1

$r^2 = 0.39$, $n = 216$, $p < 0.001$

were slope is in %, load in kg and gender is 1 for men and 2 for women.

- The relationship between RPE and the load, slope, gender and passation order is:

$$RPE = 2.6 + 0.08\ order + 0.034\ load + 0.45\ slope + 3\ gender$$

$r^2 = 0.48$, $n = 216$, $p < 0.001$, see = 0.6

Variables are like in relationship 1. "order" is the rank in which each condition was carried out by the worker.

The RPE increase with “order” express more confident or accoustumed employees to the conditions of the experiments rather than a reduction of the strain during the experiment.

- Strength strains are directly related to the slope and the load ($p < 0.001$). Relationships that bind Finit and Fsust forces to the load, the slope and gender are respectively:

Finit = 8.4 + 0.12 load + 0.96 slope + 2.1 gender relationship 2
r^2 = 59 n = 172, and residue = 5.6; p <0.001
Fsust = 0.11 load + 1.51 slope + 1.7 gender relationship 3
r^2 = 78 n = 195, and residue = 5.5; p <0.001
variables are like in relationship 1.

Figure 1 shows one of the most interesting result of this study. The more the slope increases, the more Fsust is close to Finit. In the conditions of the present study Fsust is not significantly different from Finit at 16° slope (p>0.1). The interaction of Finit/Fsust and slope is highly significant ($F_{6, 566}$ = 6.1, p <0.001).

The relationships 2 to 4 allow to built a model (Figure 2) using limits from a) [2]. Finit = 35 dN and Fsust = 25 dN for infrequent exertions and b) RPE = 12 which is generally accepted as reflecting too hard work. Load limits from the 2 origins are the same and a single graph illustrate both approaches.

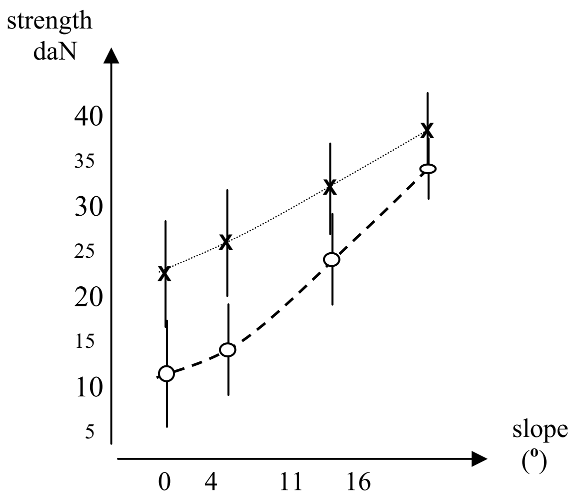

Figure 1: Evolution of average Finit (x) and Fsust (o) pushing forces according to the slope.

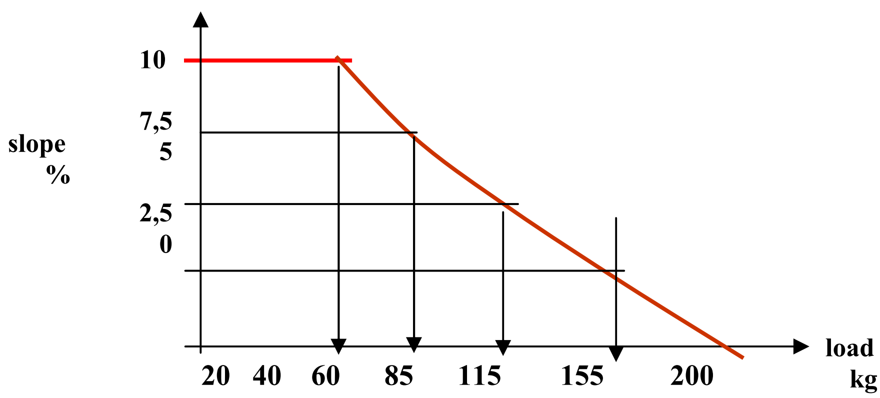

Figure 2 : Limits of load of the garbage container (red line) for different slopes which respects standards requests [2] and RPE = 12.

4. Discussion

Heart rate is an inadequate criterion in the evaluation of short duration tasks (15-30 s) made on an irregular schedule (a few hours a week). Indeed, relationship 1, although very significant, explains only one third of the variance in the HR cost. But, the sudden and significant increases in HR reflect the possible risk of heart overload in long displacements (basements, long paths ...). The container load limits (figure 2) determined from the relationships 2 to 4 built in the present study are proposed for slopes of gradients < 10 %. The slope of 16% is an almost "impossible" condition. These limits are realistic and provide a simple and protective tool for a group of employees without distinction of age or gender. This limit can even be reduced to a quasi-linear model where 200 kg is the maximum for 0% slope and 60 kg for 10% slope.

References

[1] G. Borg G, Borg's perceived exertion and pain scales, Human Kinetics, 1998, 112 p.

[2] ISO, 11228-2. Pushing and pulling strengths, Geneva, 2002.