

Strength and Perceived Effort in Repetitive Upper-Limb Tasks: An OCRA Method Analysis of 900 Workers

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ABSTRACT

Background: Work-related musculoskeletal disorders pose a significant burden on the population. The OCRA method plays a key role in assessing the risk associated with repetitive actions of the upper limbs. In this method, muscular force is evaluated based on the rate of perceived effort (RPE) reported by the worker, which can introduce subjective bias into the assessment. This study aims to determine whether testing the worker's handgrip strength can improve the accuracy of the force assessment in the OCRA method. **Methods:** Handgrip strength was measured during the risk assessment process following the OCRA method. Data were divided into specific percentile ranks based on age, gender, height, and handedness. **Results:** 903 workers from 43 different Italian companies were surveyed. There was a significant difference in handgrip strength percentiles stratified by report of an RPE > 2 and those without ($p = 0.047$). Additionally, significant differences were found in perceived effort rates (based on the OCRA method) among workers with different levels of stratified handgrip strength (dominant hand: $p = 0.04$, non-dominant hand: $p = 0.02$). **Conclusions:** Workers performing repetitive upper limb actions at various strength levels experience different perceived effort rates during tasks. These findings suggest that measuring handgrip strength is a crucial component of risk assessments using the OCRA method. To date, this study's sample size is among the largest for this evaluation method; we believe these results could be a significant step forward in improving the risk assessment process for biomechanical overload.

1. INTRODUCTION

The incidence and prevalence of musculoskeletal disorders (MSDs) have been steadily increasing over the years. Data provided by the 2021 Global Burden Disease study [1] revealed that MSDs were

responsible for 162 million DALYs (Disability-Adjusted Life-Years), accounting for 6.6% of the total DALYs in 2021 [2]. Numerous reports, such as the one presented by EU-OSHA in 2021 [3], acknowledge the strong link between biomechanical factors and MSDs in workers. Another significant

risk factor for developing MSDs appears related to the decline in muscle strength [4, 5]; or, from a different perspective, muscle strength seems to be a protective factor against MSDs. Therefore, it is essential to identify and refine suitable assessment tools that accurately measure both movement (technical actions) and muscle strength, including the expected decline associated with worker aging.

To reduce the risk of developing MSDs as a negative consequence of work-related factors (Work-related Musculoskeletal Disorders, WR-MSDs), several risk assessment procedures have been developed. These aim to evaluate the level of biomechanical overload caused by repetitive actions, manual handling of loads, pushing, pulling, and other factors. This overload may serve as a pathomechanism due to the overuse of certain muscle groups and the underuse of others [6], leading to imbalances and repetitive strain injuries [7]. One assessment tool for repetitive actions is the OCRA (Occupational Repetitive Actions) method, which is detailed in the OCRA checklist and OCRA index. It is recognized as the reference methodology by the technical standards of the International Organization for Standardization (ISO) 11228-3 "handling of low loads at high frequency," alongside other methods such as the strain index and Hal/ACGIH TLV. The OCRA method incorporates time-based risk factors like recovery periods and action frequency, allowing risk evaluation based on exposure duration across multiple tasks through multitask analysis. The final risk score generated by OCRA, used to predict the likelihood of developing upper limb WR-MSDs, is derived from six multipliers or factors: frequency, force, posture, complementary factors, recovery, and duration. For the force multiplier, the Borg CR-10 scale [8] is recommended to evaluate the amount of force needed for specific tasks. Notably, the OCRA method does not consider age or gender differences, despite their significant impact on muscle strength. Conversely, the NIOSH equation for manual material handling explicitly accounts for age and gender differences, providing different lifting indexes for men and women of various ages (under 20 or over 45 years old), whether healthy or affected by MSDs.

A key benefit of the OCRA approach using the Borg CR-10 is that workers independently assess

their perceived exertion during repetitive tasks. This micro-procedure takes only a short time and requires no special equipment. According to the instructions for applying the OCRA methodology [9], authors recommend this approach because it helps reduce bias. However, using the Borg CR-10 remains a subjective method that measures the relative internal load [10], which can also be influenced by temporary fatigue and familiarity with the task. This may lead to over- or under-estimation of effort, which could inevitably affect the force factor in the OCRA calculation. Additionally, previous reports indicate that psychosocial factors can also influence workers' perception of effort during heavy physical work [11]. To mitigate this risk, authors recommend interviewing more than one worker per task, averaging the results, and excluding operators with disabilities or "anthropometric extremes." However, this is rarely practical, and there are no specific guidelines on how to adjust (or if adjustment is necessary at all) the methodology in less-than-ideal situations.

One of the simplest tests to assess overall strength and physical efficiency is the handgrip strength test [12, 13], which has also been shown to serve as a prognostic marker for all-cause mortality [14] and disability [15]; notably, the handgrip strength test is recommended as a diagnostic tool capable of predicting the development of musculoskeletal disorders of the upper extremities [16, 17]. This test is quick to perform, requires minimal setup and explanation, and the device can be easily transported for field use. Therefore, this study aimed to explore the potential role of the handgrip strength test in a real work environment. Objectively measuring handgrip strength could serve as a helpful addition to interpreting biomechanical overload risk from repetitive actions using the OCRA method. A secondary goal was to examine whether workers with different strength levels report varying rates of perceived exertion during tasks, which could affect risk assessment.

2. METHODS

Data were collected by trained ergonomists with at least five years of experience during risk evaluation procedures. They conducted interviews with

workers at each company, gathering general health data such as stature, age, gender, dominant hand side, and handgrip strength. They also collected data for the formulation of the OCRA checklist, including working time, non-repetitive work time, rest time, video recordings of repetitive tasks, number of items processed per day, and the rate of perceived effort (RPE). The RPE was measured on a standard Borg CR-10 scale and related to technical actions that were subjectively identified as requiring muscular force. These actions, observed during recorded repetitive tasks, could involve either handling a significant load (e.g., lifting a heavy component for assembly) or performing forceful upper limb actions (e.g., tightening a bolt, sanding operations).

Handgrip strength was measured using a hydraulic dynamometer (Baseline Hydraulic hand dynamometer, Fabrication Enterprises Inc., White Plains, NY 1062, USA). The test involved the participant standing upright, with the arm at their side and the elbow flexed at 90°. Each participant completed three trials, with three minutes of rest between each attempt, and the highest result was recorded.

Handgrip strength percentiles stratified by gender, age, stature, and handedness were calculated for each participant for their dominant and non-dominant hands using the normative values presented by Spruit and colleagues [18], based on the UK Biobank database. The distribution of participants with below (<1st quartile), within (1st-3rd quartiles), or above (>3rd quartile) average handgrip percentile strength was then determined.

Participants were workers whose tasks included at least one hour of repetitive upper limb actions (but did not meet all of the quick assessment acceptability criteria), and their risk was assessed using the OCRA checklist. Participants had to be free of any current acute health condition that would be an absolute contraindication to work and were excluded if they were currently in training or had less than 6 months of experience at the tested workstation. Participants were considered outliers and excluded if their dominant handgrip strength was ≤ 5 kg.

Age groups were identified based on the age when muscle strength generally begins to decline, estimated to occur in the third decade of life, and

the age after which the decline becomes more pronounced, after the fifth decade of life [19] as cut-off points. Descriptive statistics are shown as mean, standard deviation, or median and IQR range when appropriate. Normality of handgrip data was evaluated using the one-sample Kolmogorov-Smirnov test and through visual inspection of QQ-plots and histograms.

The Wilcoxon rank-sum test for unpaired samples was performed to compare the distributions of stratified percentiles between the group that reported a “moderate” or greater effort during work tasks and the group that did not. The Kruskal-Wallis rank sum test was used to compare handgrip percentiles across three age groups. The Jonckheere-Terpstra one-sided test for ordered alternatives assessed differences in perceived exertion rates—based on the OCRA categorization (ordered as: “No exertion” < “Moderate” < “Intense” < “Near maximum”)—across grouped handgrip stratified percentiles (ordered as: “Below average” < “Average” < “Above average”). A permutation method was chosen to handle the large sample size and ties in the data, with 10000 permutations performed for each test. A significance level of $p < 0.05$ was set for all statistical tests. Percentages for age groups and perceived exertion categories were used solely for visualization purposes.

All statistical analyses were conducted using R version 4.4.2 [20] within the RStudio environment, version 2024.09.1+394 [21], utilizing packages such as tidyverse version 2.0.0 [22], dgof version 1.4 [23], pspearman version 0.3-1 [24], sjPlot version 2.8.15 [25], and DescTools version 0.99.58 [26]. Plots were generated using R with the packages ggplot2 version 3.5.1, ggpubr version 0.6.0 [27], and qqplotr version 0.0.6 [28].

3. RESULTS

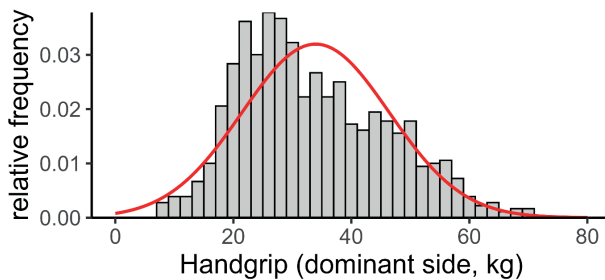
3.1. Participants’ Characteristics

Data were collected from October 2020 to October 2024 for 903 workers (899 after removing outliers; 486 Women, 413 Men), representing 41 companies across various sectors including manufacturing (such as furniture, eyewear, medical supplies, and electrical appliances; see Table S3,

Table 1. Description of the sample.

	Stature (m)	Age (y)	D Handgrip (kg)	ND Handgrip (kg)
Min	1.45	18	9.00	4.00
Max	1.97	66	71.00	69.00
Mean (SD)	1.70 (0.09)	43.59 (11.05)	33.94 (11.86)	30.19 (11.86)

D Handgrip: dominant side handgrip, ND Handgrip: non dominant side handgrip.

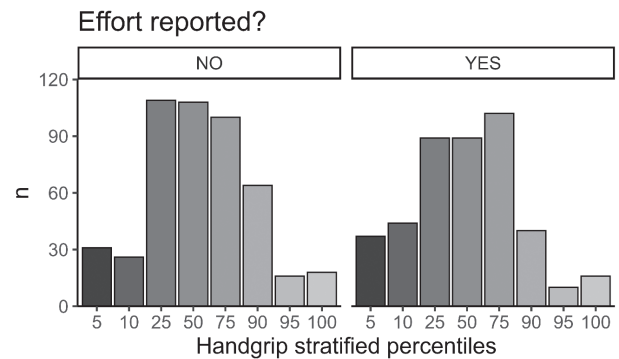
**Figure 1.** Dominant side handgrip strength (Kg) compared to a normal distribution using the same mean and SD.

available in the supplementary material), logistics, and waste management. Sample characteristics are reported in Table 1.

The Kolmogorov-Smirnov test for normality was significant for both the dominant and non-dominant sides' handgrip strength tests ($N = 899$, both p -values < 0.0001), indicating a non-normal distribution, consistent with visual inspection of histograms (see Figure 1 for the dominant side) and QQ-plots (Figures S1 and S2, available in Supplementary material, for the dominant and non-dominant sides, respectively), which show a right skewness of the data. A relative scale on the y-axis was used for Figure 1 to facilitate visual comparison with the normal curve.

3.2. Handgrip Strength Percentiles Distributions

After calculating handgrip strength percentiles, the sample was divided based on whether the participants reported any significant use of force, as defined in the OCRA methodology ($RPE > 2$), regardless of the type of task (Figure 2 and Table S4, available in the supplementary material). The groups showed significant differences in stature (No effort declared: 1.69 ± 0.09 m, effort declared: 1.71 ± 0.09

**Figure 2.** distribution of participants' handgrip percentiles according to their reporting of effort during working tasks.

m, $p = 0.0004$) and handgrip strength on the dominant side (No effort declared: 33.06 ± 12.40 kg, effort declared: 34.93 ± 12.49 kg, $p = 0.03$). For a full description of the two groups, see table S1 in the supplementary material. Wilcoxon rank-sum test between the two groups indicated a significant difference in the distribution of handgrip stratified percentiles ($W = 108375$, p -value = 0.047).

3.3. Age Groups Analysis

Handgrip strength stratified percentiles showed a variable distribution across age groups (Figure 3), which are also described in Table S2 of the Supplementary material.

According to a Kolmogorov-Smirnov test, only the distribution of handgrip data for the youngest group appears to follow a normal distribution ($D_{18-34} = 0.08$, p -value = 0.14; $D_{35-49} = 0.10$, p -value = 0.001; $D_{50-66} = 0.12$, p -value = 0.0001).

The Kruskal-Wallis test on the distribution of handgrip strength percentiles stratified by age

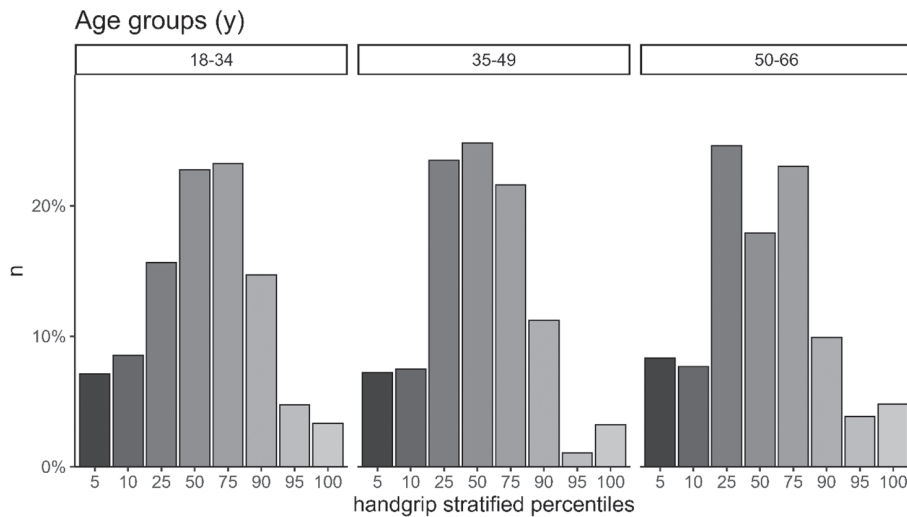


Figure 3. Percentage distribution of participants' percentiles between different age groups.

groups did not reach the significance threshold ($H = 4.08$, $df = 2$, p -value = 0.13).

3.4. Perceived Effort Values and OCRA Categories

The median RPE score was 0 with $IQR = 4$ for the dominant side and 0 with $IQR = 3$ for the non-dominant side.

The declared scores were aggregated into categories following the classification used in the OCRA method:

- RPE 0-2: no exertion.
- RPE 3-4: moderate exertion.
- RPE 5-7: intense exertion.
- RPE 8-10: near maximum exertion.

These are represented in Figure S3 and available in supplementary material. The participants were then grouped according to their respective handgrip strength percentiles (Figure 4a and 4b, dominant and non-dominant sides, respectively). Given the different sizes of the three groups, relative distributions were plotted as percentages (below average: 336, 37.4%; average: 399, 44.4%; above average: 164, 18.2%).

The Jonckheere-Terpstra test for ordered alternatives showed a statistically significant trend of

lower Borg CR-10 scores, ranging from “No exertion” to “Near maximum,” across higher handgrip strength percentile groups, from “Below average” to “Above average,” for both the dominant side ($JT = 120856$, p -value = 0.04) and the non-dominant side ($JT = 120098$, p -value = 0.02).

4. DISCUSSION

This study aimed to examine in a real-world setting whether using the handgrip strength test could serve as a useful and objective adjunct in interpreting biomechanical overload risk from repetitive upper limb actions with the OCRA checklist. The main finding was that the distribution of handgrip stratified percentiles was significantly affected (p -value = 0.047) by dividing participants into those who reported an RPE > 2 and those who did not. Among workers who reported significant effort during their tasks, 40% fell below the 1st quartile of the reference table, compared to 35% in the group that did not report significant effort. This difference is also reflected in the upper quartile distribution: 20% versus 15% in the groups that did and did not report effort, respectively.

Another interesting observation emerging from this analysis concerns data distribution. Handgrip strength values in workers performing upper-limb

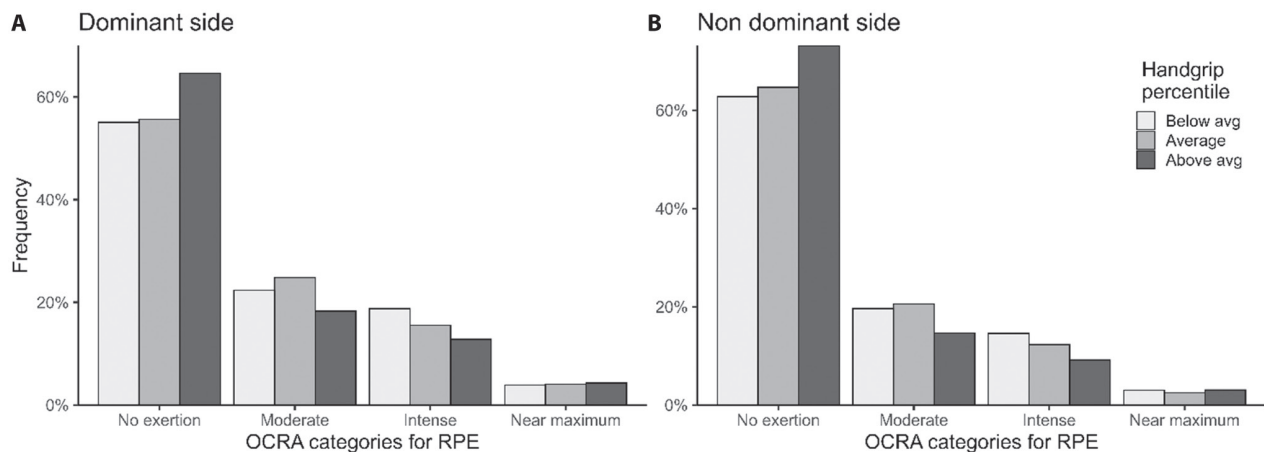


Figure 4. Percentage of rate of perceived effort declared grouped by OCRA categories and split between handgrip strength percentiles groups, **(a)** dominant side; **(b)** non-dominant side.

repetitive actions appear to deviate from a normal distribution with a right skew and show a distribution that is significantly below the expected percentiles, even after accounting for gender, age, stature, and handedness. Several possible explanations could account for the observed discrepancy: this subgroup (workers engaged in repetitive upper-limb actions) may not be representative of the general population. Additionally, the sample was not randomly selected but instead obtained during risk evaluation procedures, which could introduce selection bias despite the large sample size. One could argue that companies with higher work demands and a greater prevalence of musculoskeletal disorders are more likely to request a risk assessment; however, this process is mandatory in Italy under Legislative Decree No. 81 of 2008 (and subsequent changes) [29] and must be updated whenever there are changes in working conditions, production processes, or organization, reducing this potential bias. We instead hypothesize that the high prevalence of musculoskeletal disorders among workers, as extensively reported for both the EU and USA [30, 31], may partially explain their reduced performance in the handgrip test. Previous studies have shown significant associations between lower handgrip strength and low back pain [32], as well as a higher risk of work limitations [33]. Furthermore, an observational study by Walker-Bone et al. [34] found that lifetime exposure to physically demanding work was inversely

associated with handgrip strength (although this effect was not statistically significant after adjusting for socioeconomic confounders).

It is worth emphasizing that the data we refer to throughout this paper are not raw percentiles of handgrip strength, but already adjusted to account for age, gender, handedness, and stature, producing stratified rankings. When we divided the data into three age groups, only the youngest group followed a normal distribution, while the older groups showed a right skew, suggesting that the decline in handgrip strength with age may be more pronounced in manual workers. Although the distributions were not significantly different ($p = 0.13$), manual workers tend to have lower handgrip strength compared to individuals of the same age, gender, handedness, and stature. These points raise an important question: if workers with below-average handgrip strength are more likely to report significant effort in their tasks ($RPE > 2$), could the risk assessment process be improved by incorporating an objective measure of handgrip strength? Particularly in the OCRA checklist, the force evaluation can greatly influence the risk assessment for repetitive actions, with scores reaching over 32 points (a score of ≥ 22.5 indicates high risk) for near-maximum efforts sustained over more than 10% of the work cycle. Therefore, it is crucial that this component of the risk assessment accurately reflects the true demands of the task.

The same trend appears when examining the distribution of RPE across different handgrip strength percentile groups, for both the dominant and non-dominant sides. From fig 4 a and b, it is evident that (for both sides) the above-average group reported no exertion more often and moderate or intense exertion less frequently compared to other groups. Conversely, the below-average group reported no exertion the least and more often reported intense exertion. These trends are statistically significant ($p = 0.04$ and $p = 0.02$ for the dominant and non-dominant sides, respectively), further supporting the idea that handgrip strength influences effort perception measured with the Borg CR-10 scale during work tasks. Therefore, including a strength assessment such as the handgrip test in the risk evaluation process may help reduce subjectivity related to the interviewed worker and enhance the focus on an objective evaluation of the task itself. The differences among the three handgrip strength percentile groups diminish when considering the “near maximum” category. We hypothesize that, for very heavy lifts, the variation in handgrip strength scores becomes less relevant in determining perceived effort (e.g., for a 97 kg shaft spool and coil lifted by two workers). Additionally, since workers with lower handgrip strength scores may be more prone to WR-MSD, they might face work limitations when performing tasks that involve particularly heavy lifts.

In summary, adding handgrip strength evaluation during risk assessment is practically feasible since the test can be done with portable equipment, quickly, and with minimal risk to the person tested. A future perspective could involve applying these results to explore different methods of calibrating risk calculation related to force use, such as adjusting the declared Borg CR-10 scores for workers with very low or very high handgrip scores. Alternatively, the adjustment could be implemented further downstream, directly in the risk-score factors. Compared to the reported Borg CR-10 score, multipliers would offer greater precision, with a broader range (1-32), and the option to use decimal values for fine-tuning. Another approach might include applying different multiplying factors based on age and gender, similar to the NIOSH equation,

or directly using handgrip percentile to develop a stratified risk index that accounts for individual muscular strength differences and the potential non-normal distribution of data.

On one side, we recognize some limitations in the present study: first, we lacked information on workers' seniority, which likely plays an important role in increasing the risk of developing a WR-MSD; similarly, we did not have access to medical details of the workers interviewed and could not distinguish between healthy workers and those who had a hidden WR-MSD that did not prevent them from fully attending work. Additionally, companies and workers were not selected at random. On the other hand, we also highlight some strengths in our investigation. We collected data from over 900 workers from a diverse group of companies located in different regions of Italy. To the best of our knowledge, this is the first study exploring this aspect of the OCRA methods, and we believe it could be a significant step toward improving the risk assessment process.

5. CONCLUSION

Handgrip strength appears to be distributed differently among workers exposed to repetitive upper limb actions, showing a non-normal, right-skewed distribution compared to the general population. We hypothesize that this difference may be caused by the high prevalence of WR-MSD in this subgroup. This difference is more noticeable in workers reporting the use of force ($RPE > 2$) during any task. Conversely, workers with lower handgrip strength values (considering age, gender, handedness, and stature) are more likely to report effort during their tasks, compared to those with higher handgrip scores. In this context, adding handgrip strength assessment could provide more objectivity to biomechanical load risk evaluation, especially when it is not feasible to interview multiple workers for the same task. The evaluation and integration of the handgrip test could help refine this part of the assessment.

SUPPLEMENTARY MATERIALS: The following are available online: Figure S1. QQ-plot of dominant side handgrip strength; Figure S2. QQ-plot for nondominant side handgrip strength; Figure S3. Frequency of rate of perceived

effort declared grouped by OCRA categories; Table S2. Descriptive statistics stratified in age groups; Table S3. Number of companies evaluated by sector; Table S4. Stratified percentiles distribution split by effort declaration.

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INSTITUTIONAL REVIEW BOARD STATEMENT: The study was conducted according to the guidelines of the Declaration of Helsinki and the ethical principles of research conducted with human participants in Italy. Ethical review and approval were waived for this study, as data for this observational study were gathered during the risk assessment procedure and were processed anonymously.

INFORMED CONSENT STATEMENT: Informed consent was obtained from all subjects involved in the study.

DECLARATION OF INTEREST: The authors declare no conflict of interest.

AUTHOR CONTRIBUTION STATEMENT: G.S. and B.M. conceived and planned the investigation; B.V., P.D., and B.A. contributed to the design of the research and collected the data; F.F. and G.S. wrote the first drafts of the paper; F.F., B.V., and D.B. designed and performed the analysis; D.P.G., S.E., M.S., and D.B.A. contributed to the writing and revision of the paper and provided key insights. All authors reviewed and approved the final draft of the paper.

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APPENDIX
SUPPLEMENTARY MATERIAL

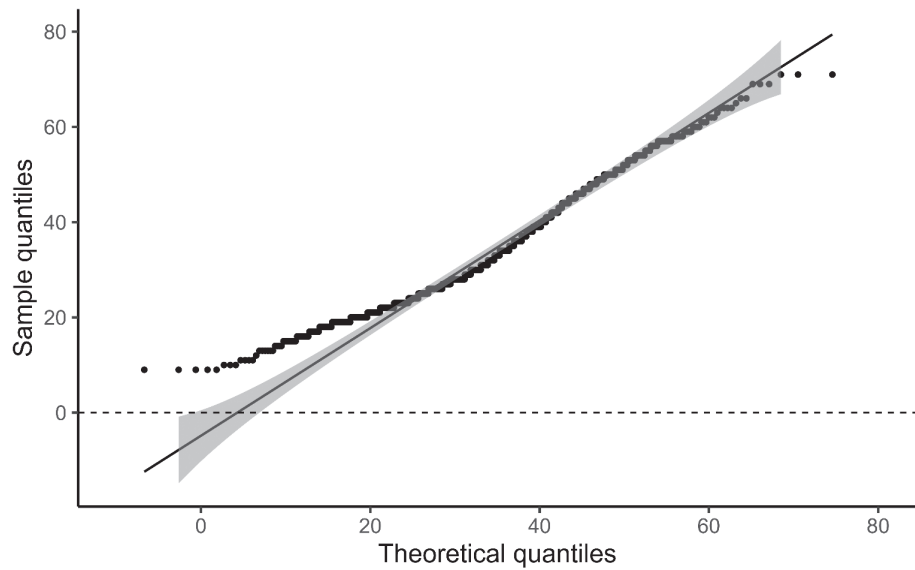


Figure S1. QQ-plot of dominant side handgrip strength.

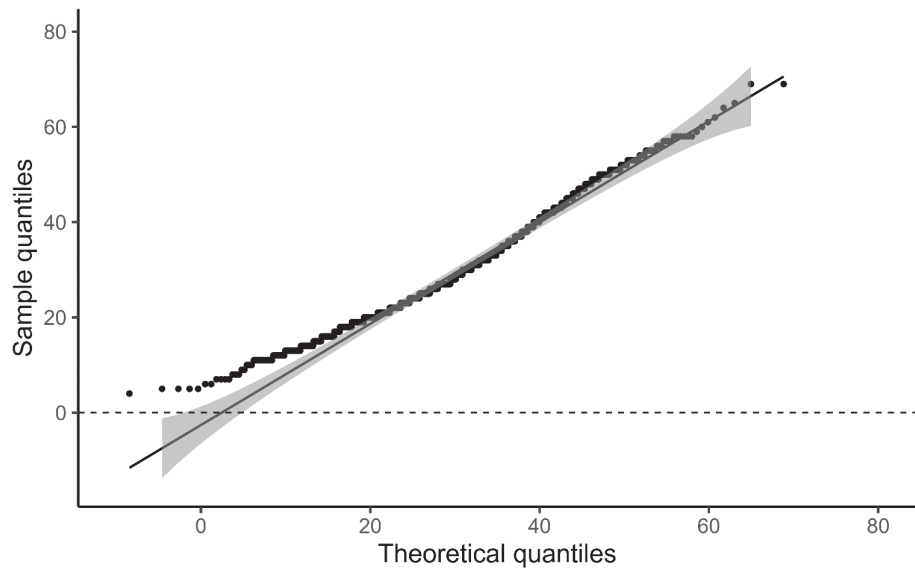


Figure S2. QQ-plot for nondominant side handgrip strength.

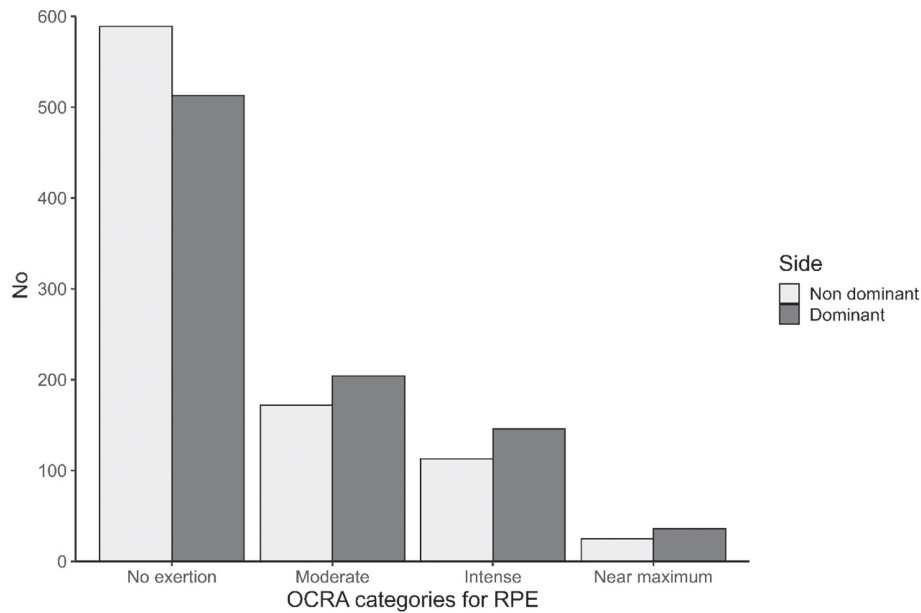


Figure S3. Frequency of rate of perceived effort declared grouped by OCRA categories.

Table S1. Descriptive statistics divided between persons that reported effort or not on the Borg CR-10 scale.

Effort declared	N	Stature (m)	Age	D Handgrip (kg)	ND Handgrip (kg)
No	472	1.69 (0.09)	43.74 (10.95)	33.06 (12.40)	29.50 (12.13)
Yes	427	1.71 (0.09)	43.43 (11.16)	34.93 (12.49)	30.95 (11.52)
p value ¹	-	0.0004	0.7	0.03	0.07

Descriptive data are presented as mean (SD); D: dominant side; ND: non-dominant side.

¹: two-sample Welch t-test, significant difference highlighted in bold.

Table S2. Descriptive statistics stratified in age groups.

Age group	N	M/F	Stature (m)	D Handgrip (kg)	ND Handgrip (kg)
18-34	211	129/82	1.73 (0.09)	38.97 (12.70)	34.39 (11.85)
35-49	375	149/226	1.69 (0.09)	32.86 (11.73)	29.31 (11.05)
50-66	313	135/178	1.69 (0.09)	31.86 (12.70)	28.41 (12.15)

M/F: number of males and females in each group; D: dominant side; ND: non-dominant side.

Descriptive data are presented as mean (SD).

Table S3. Number of companies evaluated by sector.

Sector	N companies	N workers
Bookbinding	1	6
Logistics	2	23
Meat processing	1	13
Waste disposal	1	4
Manufacturing		
Chemical products, paints, etc.	5	69
Drugs and pharmaceutical preparations	1	19
Electrical cables	2	28
Electronic components	2	123
Eyewear	3	165
Furniture	5	186
Medical instruments and supplies	2	26
Metallic products	2	15
Plastic materials and products	5	99
Shoes	1	42
Vehicle parts and components	3	38
Other manufacturing	5	47

Other manufacturing comprises: electrical parts, lighting appliances, pumps and compressors, paper products, and prostheses.

Table S4. Stratified percentiles distribution split by effort declaration.

Stratified percentile	Effort: no (n = 472)	Effort: yes (n = 427)	Effort: no (%)	Effort: yes(%)
5	31	37	6.6%	8.7%
10	26	44	5.5%	10.3%
25	109	89	23.1%	20.8%
50	108	89	22.8%	20.8%
75	100	102	21.2%	23.9%
90	64	40	13.6%	9.4%
95	16	10	3.4%	2.3%
100	18	16	3.8%	3.8%