

Wearable Exoskeletons on the Workplaces: Knowledge, Attitudes and Perspectives of Health and Safety Managers on the implementation of exoskeleton technology in Northern Italy.

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Abstract. *Background:* Exoskeleton technology (ExT) has potential to significantly improve occupational health and safety. However, studies on stakeholders' perspectives are lacking. To facilitate the implementation of ExT on the workplaces, a study was undertaken exploring specific knowledge, attitudes and perspectives (KAP) of Health and Safety Consultants (HSC). *Methods:* An online survey with quantitative and qualitative components was conducted with HSC participating to a series of qualification courses focusing on new technologies in occupational settings. Respondents rated whether they would use or recommend an exoskeleton, being assessed regarding their knowledge on ExT through a specifically designed knowledge test. Design features (n = 16) and expected benefits (n = 12) were rated and compared in terms of their importance. Regression analysis was used to identify factors significantly affecting the propensity towards the implementation of ExT. *Results.* A total of 59 HSC participated to the survey (participation rate, 90.8%): of them, 20 (33.9%) were somehow favorable towards the use of ExT on the workplaces. The most highly rated reason for potential use/recommendation of ExT was reducing the stress on joints and tendons (74.6%), followed by reducing muscle fatigue (71.2%). Among design features, higher ratings were identified for: comfort (4.53 ± 0.68), ease of setup (4.37 ± 0.72), portability (4.32 ± 0.97), minimization of falls risk (4.31 ± 0.93), ease of putting on/taking off the device (4.12 ± 1.16), and amount of physical energy needed for use (4.14 ± 0.92). Overall knowledge of ExT was quite low (knowledge score $43.2\% \pm 18.2$), with high rate of false beliefs on the protective role of ExT on musculoskeletal disorders and physical efforts, positive effects on productivity. In multivariate analysis, age < 50 years and being an internal HSC were identified as significant effectors for a positive attitude towards ExT. *Conclusions.* This study emphasizes the opportunity to spread better knowledge of actual ExT features among potential stakeholders. Moreover, design of future exoskeleton should focus on devices comfortable, highly portable, ease to setup, with a reduced risk of falls. (www.actabiomedica.it)

Key words: Exoskeleton, Wearable exoskeleton, Musculoskeletal disorders.

Introduction

Wearable Exoskeletons (WEs) are electromechanical devices that are worn by a human operator and designed to work in concert with the wearer in order to support and/or increase their physical performances, ultimately reducing musculoskeletal loads that are not otherwise abated by engineering process change (1–4).

Despite somewhat conflicting evidence, the interest for these assistive technologies has spread rapidly in manufacturing and industry (5), as the use of well-designed WEs has the potential to significantly reduce the total biomechanical strains usually associated with manual handling tasks (6–8). As weight lifting and manual handling of materials and supporting tools are main contributors to fatigue and musculoskeletal disorders (MSDs), that in turns are known to account for approximately 30% of lost time workplace injuries and illnesses (9,10), the extensive use of WEs has the potential to significantly improve health and safety on the workplaces. Unsurprisingly, the market of occupational WEs is presumed to skyrocketing in the next years, with market forecasts suggesting an average annual growth of 229%, being worth US 2.1\$ billion by the year 2021 (7,11).

Unfortunately, the ever increasing interest towards implementation of WEs in the workplaces has been influenced by images conveyed by media and fictions, with irrational fears and false hopes potentially hindering the deployment of these new technologies (3,5,7). Moreover, very little is known on attitudes, perspectives, and design features that potential operators feel as most important, eventually impairing the development of safe, functional, user-friendly devices (12). Among the occupational stakeholders, health and safety managers (HSM; in Italian “*Responsabile del Servizio di Prevenzione e Protezione*”, or RSPP) are pivotal in promoting a positive health and safety culture in the workplace. Operating as either internal advisors or external consultants in private practice, HSM evaluate the workplace environment and develop safety-management policies that identify and define the safety responsibilities of all employees. Therefore, correctly informed HSM can positively promote an appropriate use of WEs on the workplaces, while poorly informed HSM might share and disseminate

wrong information and false beliefs, ultimately impairing an appropriate design of workplaces. In this context, assessing knowledge, attitudes and personal beliefs (collectively, KAP) of HSM towards WEs is of crucial importance.

Materials and Methods

We conducted a cross-sectional study to explore KAP of HSM on the use of WEs on the workplaces and to assess their specific expectations.

Participants.

During October 2018, a convenience sample of 59 HSM was selected during formation courses on assistive technologies on the workplaces carried out in the province of Reggio Emilia (532,575 total inhabitants, for a total potential workforce of 330,735 subjects scattered across 28,351 enterprises). Sampled HSM included both “internal” (i.e. directly employed by the parent enterprise) and “external” professionals (i.e. latter working as private practitioners), of local enterprises.

Instruments.

Subjects giving their preliminary consent, before the initial courses received an email containing the link for an anonymous and fully structured questionnaire about KAP and personal expectations on the use of WEs on the workplaces. The questionnaire included a total of 38 items, divided into the following areas of inquiry:

Characteristics of the participants: age, sex, professional qualification (i.e. being internal HSM vs. external HSM in private practice), education level. Internal HSM were then asked to recall whether specific risk factors for MSDs were detectable in their parent company (i.e. manual handling, hand tools, precision tasks, repetitive tasks, manual tasks performed over the shoulders, manual tasks having an externally controlled pace).

Attitudes, Design features and Reasons to Use WEs. Participants were initially asked whether they had any

knowledge on WEs. Naïve participants were excluded from the study. Subsequently, participants were asked to rate 1 (i.e. not favorable at all) to 5 (i.e. absolutely favorable) their attitude towards implementation of WEs on the workplaces. A total of 27 statements on the use of WEs were eventually presented to the participants, including a series of reasons to use exoskeleton technology on the workplaces ($n = 11$), as well as various design and functionality considerations ($n = 16$). Items about the design of WEs were derived from previously validated questionnaires (12). Questions used a 5-point Likert scale, ranging from 1 (i.e. very unimportant) to 5 (i.e. very important).

Knowledge about WEs. A series of 10 pronouncements about WEs were derived from the institutional publication “10 idées reçues sur les exosquelettes” (13), specifically designed for disseminate current evidence on WEs across workplaces. The responses were documented as “true”, “false” or “don’t know”. A cumulative knowledge score (KS) was calculated by awarding a score of “+1” for each “correct” response, whereas for “wrong” answer and for “don’t know” a score of “0” was given, and eventually normalized to percent value.

Procedures

Before giving their consent to the survey, participants were briefed that all information would be gathered anonymously and handled confidentially. Participation was voluntary, and the questionnaire was collected only from subjects who had expressed consent for study participation. As individual participants cannot be identified based on the presented material, this study caused no plausible harm or stigma to participating individuals. As the study had an anonymous, observational design, and did not include clinical data about patients, nor configured itself as a clinical trial, a preliminary evaluation by an Ethical Committee was not required, according to the Italian law (Gazzetta Ufficiale no. 76, dated 31/3/2008).

Data Analysis

Two independent researchers ensured the accuracy of data collection, data extraction and management. Continuous variables (e.g. age, perceived

importance, knowledge score) were expressed as mean \pm standard deviation and were analyzed through Student’s t test for unpaired data or ANOVA when appropriate. Categorical variables (e.g. age categories, specific attitudes . . .) were reported as per cent values. Attitude towards the use of exoskeleton technology on the workplaces was dichotomized as somehow positive attitude (i.e. very favorable or favorable) vs. somehow unfavorable (i.e. neither favorable or unfavorable, unfavorable, very unfavorable). Similarly, statements about perceived importance of WEs use and WEs design features were dichotomized in somehow important (score 4 to 5) vs. somehow unimportant (score 1 to 3), and their distribution in respect of the outcome variable of self-reported attitude towards WEs was initially analyzed through Fisher’s exact test. All categorical variables that at univariate analysis were significantly associated with a favorable attitude towards exoskeleton technology on the workplaces (i.e. $p < 0.05$) were eventually included in a stepwise binary logistic regression analysis model in order to calculate multivariate odds ratios (OR) and their respective 95% confidence intervals (95%CI). Regression analysis was controlled for age and sex of respondents. All statistical analyses were performed by means of IBM SPSS Statistics 24.0 for Macintosh (IBM Corp. Armonk, NY).

Results

Characteristics of the sample

Demographics. As shown in Table 1, a total of 59 questionnaires were compiled and eventually retrieved (response rate = 100%): the majority of participants were males (71.2%), having a mean age of 45.3 ± 8.6 years and males were significantly older than females (47.3 ± 6.9 vs. 40.4 ± 10.4 years, $p = 0.019$). Overall, 35.6% of participants were aged ≥ 50 years or older. All participants were of Italian origin, and 42.4% of them had educational attainment including a University-level degree or higher. The majority of participants self-styled as “internal HSM” (57.6%), whereas 42.4% worked as “external consultants”. Focusing on “internal HSM”, critical tasks performed in parent company included more frequently manual

Table 1. Demographics of 59 Health and Safety Consultants (HSC) from Northern Italy participating to the survey (2018) (notes: SD = Standard deviation; WEs = wearable exoskeletons; New Media = wikis, blogs, social media, etc.)

Characteristic	
Age (mean \pm SD)	45.3 \pm 8.6
Age (years, No., %)	
	< 30 2, 3.4%
	30 – 39 13, 22.0%
	40 – 49 23, 39.0%
	50 – 59 18, 30.5%
	\geq 60 3, 5.1%
Gender (No., %)	
	Female 17, 28.8%
	Male 42, 71.2%
Educational level (university or greater, No., %)	
	High School 34, 57.6%
	University of higher 25, 42.4%
Settings of HSC activity (No., %)	
	External Consultant 25, 42.4%
	Internal Consultant 34, 57.6%
Job tasks performed in parent company (External consultants only, No., %)	
	Manual handling 20, 33.9%
	Hand tools 13, 22.0%
	Precision tasks 15, 25.4%
	Repetitive tasks 10, 16.9%
	Tasks over the shoulders 14, 23.7%
	External controls 16, 27.1%
Previous interaction with occupational exoskeletons (any, No., %)	2, 3.4%
Parent / Client company planning installation of exoskeletons (No., %)	3, 5.1%
Favorable attitude towards WEs, somehow (No., %)	20, 33.9%
Reasons to use WEs on the workplaces (important / very important, No., %)	
Reduce muscle fatigue	42, 71.2%
Reduce stress on joints/tendons	44, 74.6%
Lift increased weights	23, 39.0%
Perform job tasks quicker	14, 23.7%
Reduce rests during working shift	5, 8.5%
Reduce rests after working shifts	11, 18.6%
Reduce risks of injuries	31, 52.5%
Reduce risks of occupational disorders at...	
	1) shoulder(s) 40, 69.0%
	2) elbow(s) 30, 50.8%
	3) back 38, 64.4%
	4) knee(s) 25, 42.4%

Design features (important / very important, No., %)	
<i>Ease of putting on and taking off the device</i>	44, 74.6%
<i>Amount of physical energy needed for use</i>	40, 67.8%
<i>Length of training to become proficient</i>	40, 67.8%
<i>Overall appearance</i>	1, 1.7%
<i>Comfort</i>	53, 89.8%
<i>Walking speed</i>	24, 40.7%
<i>Range of battery life</i>	32, 54.2%
<i>Speed of battery charge</i>	26, 44.1%
<i>Ability to climb stairs</i>	25, 42.4%
<i>Ability to toilet without taking off the device</i>	30, 50.8%
<i>Portability</i>	48, 81.4%
<i>Ease of setup</i>	51, 86.4%
<i>Ability to walk on uneven surfaces</i>	42, 71.2%
<i>Purchase costs</i>	40, 67.8%
<i>Repair and maintenance costs</i>	39, 66.1%
<i>Minimizing risk of falling</i>	46, 78.0%

handling (33.9%), followed by performing precision tasks (25.4%), also over the shoulders (23.7%), with the use of hand tools (22.0%), while only 16.9% reported repetitive tasks. Interestingly enough, around a quarter of participants reported that the pace of activities was subjected to external control, such as machineries or external personnel (27.1%).

Self Assessed attitude towards WEs. Although, only 2 participants (3.4%) reported a previous interaction with WEs, with 3 further respondents reporting that the parent company or at least one client company was planning installation of exoskeleton technologies, 20 (33.9%) of participants reported a somewhat positive attitude towards exoskeleton technology.

Reasons to use WEs on the workplace. Overall, 74.6% of participants rated the reduction of stress on joints/tendons as an important/very important feature, followed by reduction of muscle fatigue (71.2%), as well as protective effects towards occupational disorders of back (64.4%) and shoulders (69.0%). On the contrary, the lowest share was reported for performing job tasks quicker (23.7%) and reducing rests during working shifts (18.6%).

Design features of WEs (Figure 1). Overall appearance of WEs was identified as a very important or "important" design features by only 1.7%

of participants, while the majority of them recalled comfort (89.8%), ease of setup (86.4%), and portability (81.4%), followed by minimizing risk of falling (78.0%), ease of putting on and taking off the device (74.6%) and ability to walk on uneven surfaces (71.2%). Again, two thirds of participants identified as "very important" or "important features" the amount of physical energy needed for use and length of training to become proficient in WE use (67.8% for both features), the costs of purchase (67.8%), and repair and maintenance (66.1%). Interestingly enough, design features such as the ability to toilet without taking off the device, to climb stairs, overall walking speed, and the speed of battery charge were reported by only half of participants or less (50.8%, 42.2%, 40.7% and 44.1%, respectively).

Knowledge about WEs

Mean KS was $43.2\% \pm 18.2$ (median 5, range 0 to 8), being not significantly greater in participants exhibiting a somehow unfavorable attitude towards exoskeleton technology ($38.5\% \pm 18.2$ vs. $45.6\% \pm 16.8$; $p = 0.156$), with an internal consistency coefficient (Cronbach's alpha) of 0.721. Focusing on single statements (Figure 2), the majority of participants were

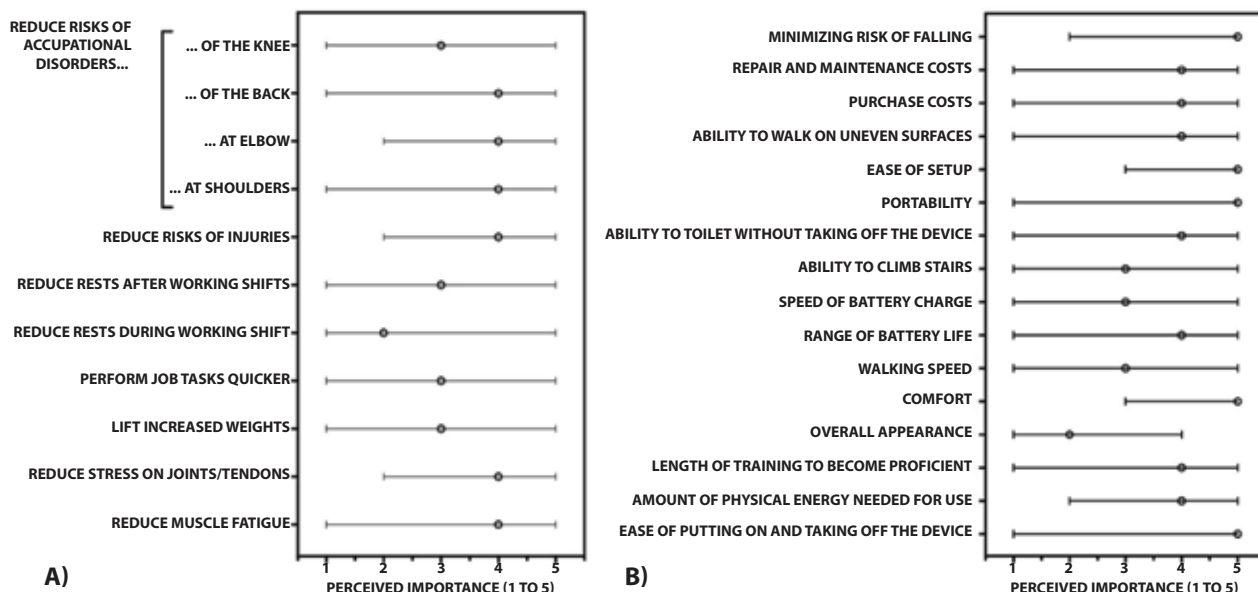


Figure 1. Perceived importance (median ± range) for using Wearable Exoskeletons (WEs) on the workplaces (a), and selected design features of WEs (b).

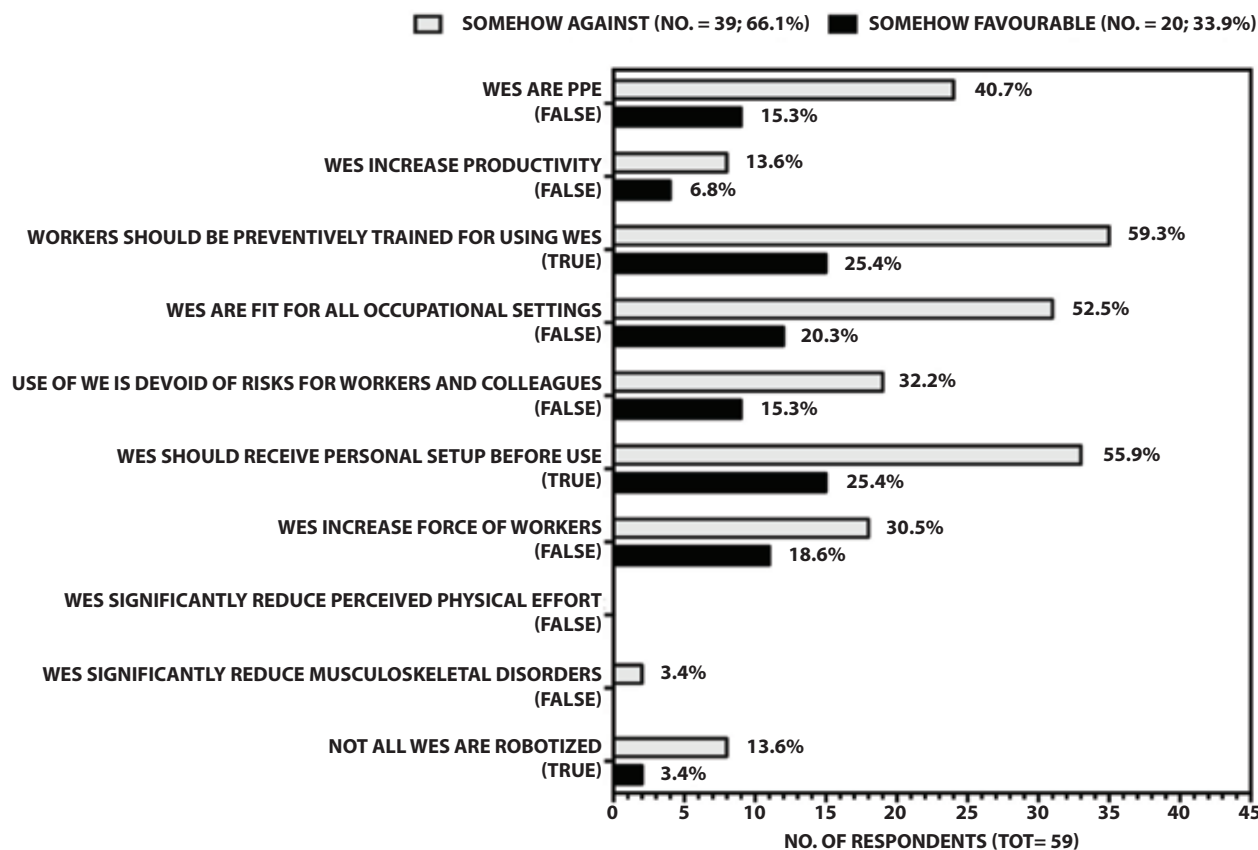


Figure 2. Knowledge test on Wearable Exoskeletons (WE) in 59 Health and Safety Managers (HSM) participating to the survey (Northern Italy, 2018) (Note: SD = standard deviation; PPE = personal protective equipment).

aware that workers should be preventively trained for using WEs, that exoskeleton should receive specific setup before use (81.4%), that WEs are unfit for all occupational settings (72.9%), and that WEs are not personal protective equipment (PPE, 55.9%). On the contrary, the large majority of respondents were unaware that WEs may be deprived of mechanized components (83.1%), and identified WEs as instruments of proved effectiveness in improving overall productivity (79.7%), while nearly all participants believed that

their use may significantly reduce MSDs (96.6%) and perceived physical effort (100%)

Univariate analysis

As shown in Table 2, subjects younger than 50 years exhibited a more positive attitude towards WEs than older participants ($p = 0.033$), and similarly being an internal HSM rather than an external one (0.015), while other individual characteristics such

Table 2. Univariate analysis of the association of individual characteristics of 59 Health and Safety Managers (HSM) from Northern Italy participating to the survey (2018) with a somehow favorable attitude towards the use of wearable exoskeletons (WEs) on the workplaces (notes: SD = Standard deviation)

Characteristic	Somehow favorable (No./20, %)	Somehow contrary (No./39, %)	P value
Age < 50 years	17, 85.0%	19, 48.7%	0.033
Male Gender	11, 55.0%	31, 79.5%	0.070
Educational level, university or greater	11, 55.0%	31, 79.5%	0.177
Settings of HSM activity as internal consultant	16, 80.0%	18, 46.1%	0.015
Previous interaction with occupational exoskeletons (any)	2, 10.0%	0, -	0.111
Parent / Client company planning installation of exoskeletons	3, 15.0%	0, -	0.055
Reasons to use WEs on the workplaces (important / very important)			
<i>Reduce muscle fatigue</i>	11, 55.0%	31, 79.5%	0.070
<i>Reduce stress on joints/tendons</i>	15, 75.0%	29, 74.4%	1.000
<i>Lift increased weights</i>	9, 45.0%	14, 35.9%	0.578
<i>Perform job tasks quicker</i>	4, 20.0%	10, 25.6%	0.753
<i>Reduce rests during working shift</i>	1, 5.0%	4, 10.3%	0.653
<i>Reduce rests after working shifts</i>	1, 5.0%	10, 25.6%	0.079
<i>Reduce risks of injuries</i>	14, 70.0%	17, 43.6%	0.097
<i>Reduce risks of occupational disorders at...</i>			
1) <i>shoulder(s)</i>	16, 80.0%	24, 61.5%	0.239
2) <i>elbow(s)</i>	9, 45.0%	21, 53.8%	0.589
3) <i>back</i>	15, 75.0%	23, 59.0%	0.263
4) <i>knee(s)</i>	8, 40.0%	17, 43.6%	1.000
Design features (important / very important)			
<i>Ease of putting on and taking off the device</i>	15, 75.0%	29, 74.4%	1.000
<i>Amount of physical energy needed for use</i>	17, 85.0%	23, 59.0%	0.076
<i>Length of training to become proficient</i>	11, 55.0%	29, 74.4%	0.152
<i>Overall appearance</i>	1, 5.0%	0, -	0.339
<i>Comfort</i>	20, 100%	33, 84.6%	0.087
<i>Walking speed</i>	10, 50.0%	14, 35.9%	0.402
<i>Range of battery life</i>	11, 55.0%	21, 53.8%	1.000

Table 2. (Continued)

Characteristic	Somehow favorable (No./20, %)	Somehow contrary (No./39, %)	P value
Speed of battery charge	9, 45.0%	17, 43.6%	1.000
Ability to climb stairs	11, 55.0%	21, 53.8%	0.177
Ability to toilet without taking off the device	7, 35.0%	23, 59.0%	0.103
Portability	17, 85.0%	31, 79.5%	0.734
Ease of setup	16, 80.0%	35, 89.7%	0.424
Ability to walk on uneven surfaces	14, 70.0%	28, 71.8%	1.000
Purchase costs	9, 45.0%	31, 79.5%	0.017
Repair and maintenance costs	8, 40.0%	31, 79.5%	0.004
Minimizing risk of falling	15, 75.0%	31, 79.5%	0.746
Knowledge Score > median (i.e. 5)	10, 50.0%	24, 61.5%	0.419

Table 3. Multivariate regression analysis. The model included: age, gender, educational achievements, activity as internal vs. external Health and Safety Manager, and perception of high relevance of the following design features: purchase costs, and maintenance costs as effector variables. A somehow positive attitude towards Exoskeleton Technology was the outcome variable (Note: OR = multivariate odds ratio; 95%CI = 95% Confidence Intervals)

Effector Variables	OR	95%CI
Age < 50 years	7.494	1.066; 52.686
Male sex	0.574	0.030; 11.088
Educational achievement, University level of higher	2.017	0.204; 19.974
Working as internal Health and Safety Manager	20.003	2.388; 167.6
Purchase costs	0.206	0.034; 1.254
Maintenance costs	0.169	0.028; 1.022

as sex ($p = 0.070$), and education level ($p = 0.177$), had no significant association with a proactive attitude towards exoskeleton technology.

Again, no significant differences were identified among the reasons advocated to promote the use of WEs on the workplaces ($p > 0.05$ for all items), while focusing on design features, subjects exhibiting a positive attitude towards WEs reported less frequently costs associated items such as purchase and repair/maintenance costs as important or very important ones ($p = 0.017$ and 0.004 , respectively).

3.3 Multivariate analysis

Multivariate analysis eventually included as effector variables: age, gender, educational achievements, activity as internal vs. external HSM, and perception of high relevance of the following design features: purchase costs, and maintenance costs. Eventually

(Table 3), only age < 50 years (OR 7.494, 95%CI 1.066 – 52.686), and working as an internal HSM (OR 20.003, 95%CI 2.388 -167.6) were identified as significant predictors for a positive attitude towards the implementation of WEs on the workplaces.

Discussion

WEs are increasingly introduced by vendors and producers as devices that can enhance workers' productivity, provide assistance to aging workers, and decrease the risk of musculoskeletal disorders. Despite the significant lack of industrial and safety standard, and the conflicting results of research studies concerning the use of exoskeletons to reduce risk factors of load handling, not only they are actually used, but WEs are increasingly prevalent in the public and private sectors, particularly in heavy industries (3–10).

In our survey, not only very few participants had actual experience in using WEs, but only 3 of them (5.1%) reported that a parent/client company was planning their implementation. Notwithstanding, nearly a third of them reported a favorable or a very favorable attitude towards WEs. Such enthusiasm may find several explanations.

First and foremost, the diffuse, somehow irrational confidence on assistive technologies (including WEs) for reducing workers exposure to biomechanical risk factors and subsequent (5,7,8,14). Not coincidentally, the sample was extensively affected by a combination of high expectations towards exoskeleton technology, and the actual lack of evidence based awareness of its potential pros and cons (5), as suggested by the unsatisfying results of knowledge tests. More specifically, the majority of participants identified WEs as devices able to significantly reduce the stress on joints and tendons, and muscle fatigue, eventually allowing the wearer to improve physical performances, tolerance to efforts, and overall productivity. Unfortunately, available evidences are conflicting. Even though some reports have suggested that the use of WEs has the potential to improve physical performances in some bodily districts, in particular at lumbosacral level (8,15–17), an increased strain was otherwise documented on other joints and muscle groups (6,7,14,18,19), with subsequent potential risks for their accelerated aging. On the contrary, WEs aiming to improve performances of the upper limbs and to mitigate bio-mechanical risk to the shoulders resulting from the use of heavy hand tools in occupational environments, may be associated with some cost to the low back (20). Moreover, recent studies on work productivity have shown that the use of WEs may be associated with an increased number of errors during precision tasks, with doubtful impacts on time requested to perform them (2,21,22).

Second, there is some evidence that workers deserve to WEs a more positive than the one towards other assistive technologies, and particularly collaborative robots. On the one hand, workers apparently like the fact that with WEs the user maintain the full control of the gesture, keeping their and potentially continuing their work even if the system breaks down (5). On the other hand, there is a diffuse perception of such devices as safe or even very safe ones (3,5,23).

However, such studies have been performed in supervised settings, with trained personnel guarding the user from injuries or misuses. As previously reported (7,8), increases in leg muscle activity have been reported for some devices (14,19); and this may occur because the external forces applied by the WEs needs to be counteracted to retain balance. This increase in leg muscle activity could contribute to lower extremity fatigue, with an increased risk for loss of balance, whose actual impact has not been carefully assessed. Moreover, As previously stated for rehabilitation exoskeletons (12), it is reasonable that when industrial WEs will be used in less controlled environments, their final instalment may require some trade-off between the safety and overall function of the devices.

In other words, our survey suggests that WEs have the potential to be accepted and used, at least initially, by potential stakeholders. However, in light of aforementioned conflicting evidences, implementation of WEs on the workplaces will require extensive attention to their design features, accurately tailoring these new devices to the working environments and to the requirements of the personnel. As previously suggested, a new device will be accepted by subjects who sees the aid as useful for their own purposes (24), quickly discarding devices that do not fulfil their personal expectation (25). Therefore, workers and employers should be aware that the existing generation of Wes have significant limitations with respect to their affordability, size, weight, speed and efficiency, being their installation and setup very long and time consuming procedures (3,5,7). Otherwise, the very high expectations on the positive impacts of WEs risk to be counterproductive towards their final acceptance.

In this regard, and despite the increasing use of WEs on the workplaces, there are no studies focusing on the perceived importance of design features among potential users and stakeholders. At the moment, similar researches have been performed only on WEs used for rehabilitation of wheelchair users (12), being the results are only limitedly comparable. For instance, aside the theme of comfort, we identified ease of setup and overall portability as the most important features, whereas previous reports on rehabilitation WEs stressed the importance of safety (e.g. risk of falling) and concerns towards the overall

costs (12). Interestingly enough, costs related features were significantly unrelated with a positive attitude towards the implementation of WEs on the workplaces, and such different perspectives were not unexpected. Currently, purchasing a WEs for personal use may cost up to 100,000€, with very few opportunities for reimbursement by health services and/or health insurances. On the contrary, not only occupational WEs may be significantly cheaper in terms of purchase and maintenance costs (for example, EKSO™ exoskeleton currently implemented by some car manufacturers costs around 6,500\$), but those costs are also borne by the employers, being outside the viewpoint of the HSM and final users as well (3,7,24).

Our study is affected by several limitations. First and foremost, our survey had a limited sample size, being gathered through convenience sampling and including 59 professionals from a very delimited geographic area, and Italy is highly heterogeneous in terms of socio-economic development, with striking differences in terms of acceptance of new technologies.

Second, since the recruitment of the participants has been voluntary, it is not possible to rule out the existence of a selection bias. Participating voluntarily could be due to a proactive attitude or greater knowledge about these technologies. In the same way, the fact of not participating could be understood as a negative attitude or a lack of propensity on WEs and assistive technologies.

Third, the study population, i.e. HSM, included only subjects having a high or even very high qualification, both in term of personal education and in empirical experience with industrial technologies: as a consequence, generalization of our results to all potential users and stakeholders may be cautiously applied only to similarly highly developed industrial settings.

Finally, we cannot rule out a possible social desirability bias. In other words, our results might be affected by an implicit misreporting, because of subjects' answering to questions in a manner that will be viewed favorably rather than factually.

Conclusions

In conclusion, our explorative study suggests that HSM exhibit a good propensity towards the

implementation of WEs on the workplaces. As this positive attitude comes with a relatively high prevalence of false beliefs and misunderstanding on the actual properties of these new assistive technologies, our results stress the relevance of tailored training and educative programs. These interventions should be aimed to remove the images on WEs still conveyed by media and fictions, as irrational fears and false hopes may both hinder their deployment among an ever older working population.

Disclaimer: This paper describes the results of a retrospective analysis from open, anonymous and aggregate data. The Italian legislation does not entail an ethical approval in this type of study and for this reason a formal ethical clearance was not required. Patient data were preventively anonymized by the source company, and no specific activity on human subjects was undertaken. Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article. The facts, conclusions, and opinions stated in the article represent the authors' research, conclusions, and opinions and are believed to be substantiated, accurate, valid, and reliable. However, as this article includes the results of personal researches of the Authors, presenting correspondent, personal conclusions and opinions, parent employers are not forced in any way to endorse or share its content and its potential implications.

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