ErgonAir: A quasi-experimental study on the effects of a job specific kinetic training on the musculoskeletal load of airport luggage handlers

Johann Popp (johann.popp@haw-hamburg.de)
Hamburg University of Applied Sciences (HAW Hamburg)
Jamal Choudhry
Hamburg University of Applied Sciences (HAW Hamburg)
Martin Keuchel
Institute of Occupational Health, Safety and Ergonomics (ASER)
Natalie Krämer
Hamburg University of Applied Sciences (HAW Hamburg)
Andreas Schäfer
Institute of Occupational Health, Safety and Ergonomics (ASER)
Patrick Serafin
Institute of Occupational Health, Safety and Ergonomics (ASER)
André Klussmann
Hamburg University of Applied Sciences (HAW Hamburg)

Research Article

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Abstract

Background: Physical demands at work are a major source of work incapacity, resulting in significant expenditures. According to EU directive 90/269/EEC, occupational manual handling of loads needs to be avoided by technical and organisational measures. If this is not possible or sufficient, additional measures can be implemented, that focus on behavioural changes in the workers. This study evaluates how an educational training program developed for luggage handlers at Hamburg Airport effects their musculoskeletal load.

Methods: This quasi-experimental open-label parallel group trial allocated workers into two groups, one involves the educational training program and the other group receiving no intervention. Due to the COVID-19 pandemic, the main follow-up observation had to be carried out 3-6 months after baseline instead of 7 months. The program consisted of 16 sessions in three simulated work scenarios. Transfer into practice was enhanced through visitations to the work place. The primary outcome was the weighted cumulative musculoskeletal load of the back, knee and shoulder. We assessed this by using a motion-capturing system and video recordings in order to calculate the cumulative weighted degree-seconds for each body region.

Results: We recruited 52 male participants (mean age = 36, 39; sd = 10, 9.5) for the study and lost five during the follow-up period, resulting in total 33 participants in the intervention group and 14 in the control group. Observations were not complete for all participants, thereby resulting in sample sizes of 32, 43 and 25 in the different work scenarios. For the scenario of loading the luggage at the luggage wagon the adjusted difference between intervention and control group for the weighted cumulative musculoskeletal load of the back was -1,455 weighted degree-seconds (°s) (95%-CI -2,517 – -393), 2,227 °s (1,644 – 2,810) for the load of the knees and 813 °s (-523 – 2,150) for the load of the shoulders. After Bonferroni correction for nine tested hypotheses, only the results for the knees were statistically significant. There were no significant differences in the other two scenarios.

Conclusions: The intervention induced behavioural changes in some working scenarios. Physical load decreases for the back and increases for the knees.

Trial registration: DRKS00024583

Background

Sick leave is a considerable health burden for individuals and for national economics. The German Ministry of Labour and Social Affairs estimates yearly costs of 145 billion Euro due to sick leave. Of this, musculoskeletal disorders attributes 22% of the burden to [1]. The EU directive 90/269/EEC on work related handling of loads [2] aims on the improvement of health and safety of workers at work. It requires employers to take technical or organisational measures to avoid or reduce the need for manual handling of loads. If this is not possible or insufficient, the employer has to take measures to minimise the risk associated with manual handling of loads. These measures can be educational training programs for the employees that try to teach less burdensome handling behaviour.

Although the effects of such educational training interventions have been evaluated in controlled trials and systematic reviews, it remains difficult to give general recommendations, because of ambiguity in the classification of the broad scope of different measures that have been investigated [3]. For example the interventions of two randomised controlled trials, that studied educational training in luggage loaders at airports where a either single a 30 minutes training accompanied by an educational video and brochure in one case [4] or in the other case lifting instructions given in three group sessions with overall duration of five hours [5]. It seems that interventions that focus only on knowledge transfer are ineffective but interventions that combine theoretical input with practical training of specific movement patterns have some preventive effect on musculoskeletal disorders [3]. Available research is mostly focused on disorders of the back [3, 6–8] in contrast to other parts of the musculoskeletal system [9]. Most of the studies mainly investigate pain, sick leave and economic consequences as outcomes. The causal chain between the intervention and those outcomes remains unexplained, because the behavioural change in workers that is needed to produce an effect is rarely investigated. If that is the case, it is mostly detected by self-report questionnaires and not by direct observation [10].

This study investigated, if an intensive and workplace-specific educational training program for airport luggage handlers induces habituation of movement patterns that are less physically demanding for the workers back, knees and shoulders.

Methods

Study Design

The ErgonAIR (Evaluation of measures to reduce physical loads on ground handling employees at Hamburg Airport) project was approved by the CCG ethics committee of the University of Applied Sciences Hamburg. It was registered retrospectively 31.08.2021 at the German Clinical Trials Register with the code DRKS00024583.

It consisted of a feasibility study followed by an evaluation study. This is a report of the evaluation study. It is a single-centre, prospective, non-randomised trial at Hamburg Airport with one group receiving a work-specific educational training over 16 weeks and one control group without intervention. Study data was planned to be collected from September 2019 to June 2020 for both groups at baseline and 7 months after baseline again. Additionally, the intervention group was planned for observation on completion of the training 3-4 month after baseline. This was postponed due the COVID-19 pandemic and the resulting restrictions in air traffic. Therefore, the investigators had to change this plan to just one follow-up observation for both groups 3-6 months after baseline.

Participants

The study participants are workers in luggage handling at Hamburg Airport that with no previous kinetic training and are employees for a minimum of 50% of a normal working week. The participants work task is to load pieces of luggage from and to a luggage wagon. Some of them also handle luggage inside the cargo compartments of the airplanes in a kneeling position. The study procedures were performed directly at the airport.

Intervention

The educational training program was developed and executed by a company that was in charge for occupational health management of luggage handlers at Hamburg Airport. It was tailored to the specific work situation of this population. During the development of the program, three working scenarios were identified that are part of the usual routine for the workers and are especially demanding for the musculoskeletal system of the workers. These are loading luggage from and to the luggage wagon, pushing and pulling the luggage wagon manually as well as handling luggage inside the airplanes cargo compartment. For the training, the work environments of those scenarios were simulated in a laboratory setting in close proximity to the luggage handlers break room. An attempt was made to simulate the real working conditions in the laboratory setting as realistically as possible. A luggage conveyor belt and an airplane luggage compartment was re-enacted. This was done with the involvement of the luggage handlers. In the feasibility study, the test subjects were asked whether they still found relevant differences. After that, slight adjustments were made.

The actual training consisted of 16 sessions, with a duration of 30-45 minutes. One to three workers participated in each session and there were 1-2 sessions per week. In the first session, the performance of the work scenarios by each participant were videotaped and then discussed with a trainer. The following sessions each consisted of theoretical lessons followed by demonstration and training of specific ergonomically preferable motion sequences. The main focus was avoiding unfavourable postures and movements, such as bending and twisting the upper body at the same time or intense leaning forward without supporting themselves. A detailed manual describes structure and contents of each training session. Furthermore, the trainers visited the participants during their usual working routine and discussed feasibility and transfer of the taught motion techniques to the real work situation. The team of trainers consisted of five people, one sports scientist, one physiotherapist and three undergraduate students of health sciences.

Outcomes

We observed the physical load on the musculoskeletal system regarding back, knees and shoulders directly in the laboratory using the commercially available sensor-based motion capturing system Xsens MVN Avinda (Xsens: Enschede, The Netherlands) in combination with the computer software Xsens MVN Analyse (version 2020) and INDUSTRIAL ATHLETE version 1.24.1 (scalefit: Cologne, Germany). The joint angles were recorded at a sampling rate of 30 Hz. Moreover, video recordings of the motion sequences were analysed visually, to extract certain evaluation parameters visually. The assessment of musculoskeletal load was based on ISO 11226 [11] and DIN EN 1005-4 [12]. The main parameter for the load of the back was the angle of trunk inclination. The main parameter for the load of the knees was the angle of knee flexion and for the load of the shoulders, it was the angle of upper arm elevation. Then the measured angles were multiplied by the duration (i.e., 1/30 second due to sampling rate of 30 Hz). Finally, these were further weighted and subsequently summed up to a measure of weighted degree-seconds (°s). The weighting factors are observations of concomitant rotation or lateral inclination, one-versus two-handed performance, lifting vs. gliding movement, arm support during bending of the torso, bending and rotation of the head, times with or without load, jerkily acceleration of the luggage wagon as well as acceleration of the luggage wagon with or without body tension. The weighting took into account both positive and negative effects on the physical load. This results in three weighted sum parameters for the cumulative load of the back, knees, and shoulders, which represent a quasi-exposure dose for each of the three working-scenarios handling luggage at the luggage wagon, pushing and pulling the luggage wagon and loading luggage inside the airplane cargo compartment.

As secondary outcomes the participants were asked for musculoskeletal symptoms during the last four weeks, using the Nordic Musculoskeletal Questionnaire [13, 14]. Furthermore, three relevant Key Indicator Methods (KIM) [15–20] were used to estimate physical workloads and probability of physical overload for the investigated work tasks. Predictors were the exposure levels of the KIMs: Level 1 (< 20 points): low exposure, physical overload is unlikely to occur, level 2 (20 to <= 50 points): slightly increased exposure, physical overload possible for particular groups of employees, level 3 (50 to <= 100 points): substantially increased exposure, physical overload possible and level 4 (>= 100 points: high exposure, physical overload is likely to occur. To cover the perspective of the participants self, we asked the intervention group for feedback to the training using a self-developed questionnaire. Moreover, the planned evaluation based on the Work Ability Index [21] was not performed, because of the protocol amendment applications due to the COVID-19 pandemic.

Statistical methods

Descriptive analysis was done using frequencies and proportions for nominal data as well as the mean and standard deviation or median and quartiles for metric data. The results are presented graphically as a combination of dot-plot, spaghetti-plot and boxplot to allow the assessment of longitudinal effects on the individual and at the group level.

Differences in the load for the back, knees and shoulders were estimated in complete cases linear regression models of ANCOVA-type using the load at baseline as a covariate [22]. The models were adjusted for body size, body weight and length of occupation in the current job because these factors had relevant impact on the results of the feasibility study. We checked if the data met the model assumptions and applied robust bootstrap methods because of some violations of the assumptions of normality of the residuals and homoscedasticity [23]. The significance level is $p < 0.05$ and effect sizes are reported as differences in weighted degree-seconds together with their 95% confidence intervals. Bonferroni correction was applied for the testing of nine hypotheses to the interpretation of the p-values [23]. In addition, sensitivity analysis war performed for alternative models that either included different adjusting factors or that handled missing values in a different way [23, 24].

In a power-analysis using data from the feasibility study, a sufficient total sample size of 46 was calculated to detect differences of 10% or greater with a power of 80%.

The data preparation and analysis was carried out with R [25] and additional packages ggplot [26], cowplot [27], car [28], boot [29, 30] and mice [31].

Results

There were 593 possibly eligible workers at Hamburg Airport, 41 were recruited to the initial feasibility study (see Fig. 1). 12 participants from the control group of this feasibility study were included to the intervention group of the evaluation study and added 40 newly recruited workers to either the intervention or the control group. Finally, 34 participants were allocated to the intervention group and 18 to the control group. The baseline observations were performed from September to December 2019 and the first follow-up observations from January to May 2020. The COVID-19 pandemic caused substantial delays in the execution of the training and the follow-up observations. For this reason, the decision was made, not to perform the second follow-up but to use the data of the first follow-up observations for the main analysis. One participant from the intervention group withdrew his consent of participation, leaving 33 workers that completed the educational training intervention. Moreover, four participants were lost from the control group during follow-up because of the altered working conditions during the COVID-19 pandemic, leading to 14 participants in the control group that completed the study. The study population was further subdivided into 29 participants who usually work inside the airplanes cargo compartment (and who received special training for this working environment) and 18 who did not usually work inside the airplane cargo compartment.

The special working conditions during the COVID-19 pandemic made it challenging to schedule the observation sessions for the primary outcomes, resulting in complete data of 22 intervention group participants and 12 control group participants for the scenario of loading at the luggage wagon. Regarding the scenario of manual pushing and pulling the luggage wagon, complete data was gathered from 32 participants of the intervention group and 11 of the control group. In regard to the work scenario inside the cargo compartment, the complete observations were 17 participants of the intervention group and eight from the control group. Table 1 displays the baseline properties of the sample.

Table 1

Baseline properties of the ErgonAir sample.

	Intervention group (n = 34)		Control group (n = 18)	
	n (%)	Mean (SD)	n (%)	Mean (SD)
Age		36 (10)		39 (9.5)
Height (cm)		177 (4.9)		176 (5.2)
Weight (kg)		86 (14.4)		91 (17.4)
Self-perceived health (0-10)		7 (2)		8 (1.7)
Self-perceived fitness (0-10)		6 (1.7)		6 (1.9)
Performing sports regularly	9 (26%)		5 (28%)	
Smoking	24 (71%)		10 (56%)	
Working years		7 (6.5)		7 (8.4)
Years in current job		5 (5.8)		7 (8.5)

For the intervention group the duration between the baseline observation and the start of the educational training was 1 to 56 days with a median of 7 days. The time span for the completion of the training ranged from 7 to 16 weeks. The duration between baseline and follow-up observation was 9 – 23 weeks for the intervention group and 20 – 27 weeks for the control group.

Primary outcomes

The weighted sum parameters for the back, the knees and the shoulder region are shown in Fig. 2. In regards to the work scenario of luggage handling at the luggage wagon, the exposure for the back decreased from baseline to the follow-up observation in both groups but was more pronounced in the intervention group. In the intervention group, the median load for the back was 4,599 °s at baseline vs. 2,751 °s at the follow-up observation. For the control group it was 5,908 °s vs. 4,914 °s. The load for the knees increased from baseline to the follow-up observation in the intervention group (median: 1,586 °s vs. 4,096 °s), whereas there was a slight decrease in the control group (median: 1,934 °s vs. 1,864 °s). The strain for the shoulders remained constant over time for the intervention group (median: 7,826 °s vs. 7,588 °s), however decreased in the control group (median: 9,101 °s vs. 7,012 °s).

For the load of the back, the adjusted difference between intervention and control group was estimated at -1.455 °s (95% confidence interval (CI): -2,617 – -393) (see Table 2). After the intervention, the workers demonstrate moving patterns that were less straining for the back (like bending and rotation). This advantage is lowered by the fact that they needed a longer time for the observed working process. The estimated adjusted difference between groups for the load of the knees was 2,227 °s (CI: 1,644 – 2,810) and for the shoulders 813 s° (CI: -523 – 2,150). Solely the difference for the knees was statistically significant after Bonferroni correction for nine tested hypotheses.

Table 2

Estimated group differences of musculoskeletal load during luggage handling at the luggage wagon (n = 34).

					Confidence interval	
Parameter	Estimate[a]	SE	T-value	P-Value[b]	2.5%	97.5%
Group difference (back)	-1455	518	-2.81	0.009	-2517	-393
R^2 = 0.58; F = 10.48 (df: 5, 28) p<0.001						
Group difference (knees)	2227	284	7.83	<0.001	1644	2810
R^2 = 0.67; F = 18.22 (df: 5, 28) p<0.001						
Group difference (shoulders)	813	652	1.25	0.223	-523	2150
R^2 = 0.30; F = 2.88 (df: 5, 28) p = 0.032						

[a] Weighted grade-seconds (°s), adjusted for baseline exposure, height, weight and years in actual working position.

[b] Bonferroni corrected significance level for nine tested hypotheses is 0.5 / 9 = 0.00556.

In respect to the work scenario of pushing and pulling the luggage wagon, the observed load of the back and the knees slightly decreased over time in both groups. Regarding the load of the back the median at baseline was 1,935 °s for the intervention group and 2,004 °s for the control group versus 1,637 °s and 1,495 °s at follow-up. Furthermore, the median loads of the knees were 2,695 °s vs. 2394 °s in the intervention group and 2,697 °s vs. 2,356 °s in the control group. Finally, the load of the shoulders increased for the control group (median: 3,794 °s vs. 5,184 °s) while it was constant (median: 4,236 °s vs. 4188°s) for the intervention group.

The adjusted group differences for the load of the back were estimated at -240 °s (CI: -981 – 501), for the knees at 79 °s (CI: -254 – 412) and for the shoulders at -933 °s (CI: -1,920 – 54). None of the models showed statistical significance in the F-Test (see Table 3).

Table 3

Estimated group differences of musculoskeletal load during pushing and pulling the luggage wagon (n = 43).

					Confidence interval	
Parameter	Estimate[a]	SE	T-value	P-Value[b]	2.5%	97.5%
Group difference (back)	-240	366	-0.66	0.514	-981	501
$R^2 = 0.23$; F = 2.451 (df: 5, 37) p = 0.051						
Group difference (knees)	79	164	0.48	0.634	-254	412
$R^2 = 0.17$; F = 2.23 (df: 5, 37) p = 0.072						
Group difference (shoulders)	-933	487	1.92	0.063	-1920	54
$R^2 = 0.20$; F = 1.45 (df: 5, 37) p = 0.229						

[a] Weighted degree-seconds (°s)), adjusted for baseline load, height, weight and years in actual working position.

[b] Bonferroni corrected significance level for nine tested hypotheses is 0.5 / 9 = 0.00556.

Regarding the work scenario of loading luggage inside the airplanes cargo compartment, the load for the knees was remarkably high. This may be due to the workers staying in a kneeling position during the whole work process. There was a slight increase in both groups from baseline to follow-up observations. In the intervention group the median was 18,671 °s vs. 21,043 °s and for the control group 20,459 °s vs. 21,985 °s. The increase can be attributed to overall duration of the work process, which was longer in the follow-up observation than at baseline. The median load of the back for the intervention group decreased from 4,885 °s to 4,741 °s and in the control group from 6,788 °s to 5,882 °s. The median of the load of the shoulders increased from 11,399 °s to 13,434 °s in the intervention group whereas in the control group showed a decrease from 11,617 °s to 9,720 °s. For this work scenario, the simplest linear models had to be performed on these data, adjusted solely for baseline load and with non-robust standard errors, because of the small sample size of valid observations.

Table 4

Estimated group differences of musculoskeletal load while working in the airplanes cargo compartment (n = 25).

Parameter	Estimate[a]	SE	T-value	P-Value[b]	Confidence interval 2.5%	97.5%
Group difference (back)	-530	588	-0.9	0.378	-1,750	690
$R^2 = 0.34$; F = 5.709 (df: 2, 22) p = 0.01						
Group difference (knees)	1,371	1,806	0.76	0.456	-2,374	5,117
$R^2 = 0.27$; F = 3.997 (df: 2, 22) p = 0.033						
Group difference (shoulders)	3,979	1,494	2.66	0.014	881	7,077
$R^2 = 0.48$; F = 4.036 (df: 2, 22) p = 0.032						

[a] Weighted degree-seconds (°s), adjusted for baseline load.

[b] Bonferroni corrected significance level for nine tested hypotheses is 0.5 / 9 = 0.00556.

The estimates for the group differences were -530 °s (CI: -1,750 – 690) for the load of the back, 1,371 °s (CI: -2374 – 5117) for the load of the knees and 3,979 °s (881 – 7,077). None of these estimates was statistically significant after Bonferroni correction (see Table 4).

Secondary outcomes

The prevalence of lower back pain (during the past four weeks) decreased in both groups from baseline to follow-up, from 62% to 39% in the intervention group and from 56% to 43% in the control group. The prevalence of knee pain decreased from 44% to 18% in the intervention group and to a lesser amount from 17% to 8% in the control group. The prevalence of pain in the shoulders had a slight increase from 44% to 45% in the intervention group but a decreased from 33% to 14% in the control group. The prevalence of neck pain decreased from 44% to 21% in the intervention group and slightly increased from 28% to 29% in the control group.

In respect to the scenario of loading at the luggage wagon with values extrapolated to an eight-hour shift, the Key Indicator Method for Lifting Holding and Carrying (KIM-LHC) estimated decreasing loads over time for both groups (121 to 107 points for the intervention group and 126 to 121 for the control group). Nevertheless all estimations indicated a high risk of health problems (for the meaning of the values, see the methods chapter). The Key Indicator Method for Whole-Body Forces (KIM-BF) estimated a substantially increased risk of health problems with a decreasing tendency for the intervention group (70 to 62 points) and constant 66 points for the control group. The Key Indicator Method for Pushing and Pulling of loads (KIM-PP) indicated a slight increase of the risk for health problems due to the pushing and pulling of the luggage wagon with small differences between groups and time points (40-43 points). In the scenario of loading inside the airplanes cargo compartment the KIM-LHC score decreased in the intervention group from 211 to 166 points and increases in the control group from 196 to 200 points. The risk for health problems was high in both groups. The KIM-BF indicated a substantially increased risk of health problems with values between 96 and 98 points for both groups at all observation time points.

The participants of the educational training program assessed the program with a mean overall rating of 9.52 on a scale from 0 = "would not recommend" to 10 = "would absolutely recommend". They participants largely agreed with the methodological structure of the program. The general impression was, that participation lead to less health complaints, increased wellbeing, a better understanding of physical loads on the musculoskeletal system, preference to ergonomic work methods and an improved general health behaviour. In regards to the potential of improvement, the participants articulated the desire for additional muscle training and more support from supervisors. A minority voiced wishing extra visits at the work place to transfer the training in the laboratory to the actual work situation; some felt that the program covered this aspect sufficiently.

Discussion

We have observed some behavioural changes in the intervention group that can be attributed to the educational training program, because they were not – or to a lesser amount – seen in the control group. For the working scenario of loading at the luggage wagon the intervention group developed moving patterns that were less demanding for the back however more demanding for the knees. Although the change for the load of the back was not statistically significant after Bonferroni correction, this interpretation seems to be plausible, because it was an important content of the educational training to bend the knees instead of the back. The workers developed a moving pattern that is less demanding for the back. Nevertheless, after the training they needed a longer time to perform the task, which counteracts the beneficial effect of the behavioural change. In combination, the cumulative load of the back lowers to a small amount only. Regarding the working scenario inside the cargo compartment of the airplane, we saw an increase in the load of the shoulder region in the intervention group compared to a decrease in the control group. This can either be explained by participants supporting themselves more frequently with one hand after the training when bending forward. Although this leads to a reduction in the load on the back, it also increases the load on the shoulders. The increased cumulative load may also be due to the subjects needing more time for the same activity after the intervention. The major musculoskeletal load factor in this work scenario appears to be knee flexion, which did not change as a result of the training program and can be attributed to the spatial conditions in the airplane cargo compartment. In respect to the working scenario of pushing and pulling the luggage wagon, the intervention attributes no relevant changes in musculoskeletal load.

Concerning the secondary outcome of self-reported pain, the reports show no differences between the groups for back pain, but a decrease for pain in the knees in the intervention group, which was more pronounced than in the control group. This contradicts the finding of an increased knee burden in the primary outcome. The pain of the shoulder seems to get better for the control group and not for the intervention group. However, pain in the neck decreases for the intervention group but not for the control group. These inconsistent findings could have been due to the COVID-19 pandemic and the resulting restrictions in air traffic and thus changed work conditions during the follow-up. However, none of the observed differences between groups and time points leads to a different classification of health risks according to the applied Key Indicator Methods.

The classification of this study to be a randomised controlled trial (RCT) was inevitable because of errors during the process of randomisation and allocation of participants. Nevertheless, the data can be interpreted properly in the sense of a quasi-experimental trial. This is due to controlling potential systematic group differences by entering baseline observations of the outcome into the statistical model.

Due to the COVID-19 pandemic and the resulting restrictions in air traffic we had to adapt the trial schedule massively during the observation period. The duration between baseline and the first follow-up observation differed substantially between the participants. This may have led to smaller observed differences between study groups. Nevertheless, no indicators of systematic bias were seen. Long-term effects could not be analysed, because the second follow-up observation had to be cancelled.

Observations of the work scenario inside the simulated airplane cargo compartment were limited to a small subgroup of participants. This resulted in applying potentially oversimplistic statistical models to analyse this work scenario. Therefore, the results should be generalised with caution.

We did not perform any blinding procedures regarding participants and staff. Therefore effects of the intervention may be underestimated, because the workers communicated the content of the educational intervention to members of the control group, thus indirectly learning to handle the luggage in in an ergonomically favourable way. Furthermore, non-blinding of the study personnel might have led to an overestimation of the effects. As the assessment of the primary outcomes was mainly an automated process calculated from objective data, we assume that the risk for substantial bias is small.

The differentiated outcome parameters of our study are categorised into the three body regions back, knees and shoulders. Although, this is an advantage compared to most of the published studies that focus only on the load for the back [3–8]; nevertheless, an overall estimation of musculoskeletal load is produced using the secondary outcome of KIMs, but not for the primary outcomes. Specifically the study shows that educational training, that intends to lower the load for the back, can increase the load of other body regions. Nonetheless, concluding which of them leads to a better overall health status was not possible. Monitoring long-term observations of the health status and sick leave data can possibly add information to answer this question.

The results are consistent with previously published findings, that educational training on luggage workers has small effects on their musculoskeletal load.

Conclusions

The educational training program with simulated work scenarios could be successfully integrated into the working routines of luggage handlers at the Hamburg Airport. Although some of the workers mentioned preferring more muscle training, they value the program and recommend it to other workers. The results support the conception, that behavioural measures alone are not sufficient to decrease occupational musculoskeletal load. This is compatible with the European politics to prefer technical and organisational over behavioural workplace measures. Finally, long-term studies are recommended to investigate the musculoskeletal load of different body regions and their effect on overall health.

Abbreviations

ANCOVA: Analysis of covariance

CI: 95% confidence interval

Df: Degrees of freedom

KIM-PP : Key Indicator Method for assessing and designing physical workloads with respect to manual pushing and Pulling of loads

KIM-LHC: Key Indicator Method for assessing and designing physical workloads with respect to manual Lifting, Holding and Carrying of loads ≥ 3 kg

KIM-BF: Key Indicator Method for assessing and designing physical workloads with respect to Whole-Body Forces

SE: Standard error

Declarations

Ethics approval and consent to participate:

The Study was approved by the CCG ethics committee of the University of Applied Sciences Hamburg under the registration number 2018-13. Informed consent was obtained from all participants. All study procedures were conducted according to the declaration of Helsinki [32], the guidelines for Good Epidemiological Practice (GEP) [33] of the German working group for epidemiology, the International Code of Ethics for Occupational Health Professionals [34], the German Bundesdatenschutzgesetz [35] and the General Data Protection Regulation EU 2016/679 [36].

Consent for publication:

Not applicable

Availability of data and materials:

The datasets generated and analysed during the current study are not publicly available due the fact that it is a small sample from one work place and therefore it is unable to ensure that data can be traced back to single participants. Nevertheless, they are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

JP performed the statistical analysis and drafted the article, JC planed and coordinated the execution of study procedures and performed the interviews, MK and AS prepared videos and Xsens-data for statistical analysis, NK was co-developer of the model to measure physical load and was physiotherapeutic adviser, PS developed the model to measure physical load, planned and performed the transfer of video and Xsens-data into interpretable observation parameters and applied Key Indicator Methods, AK initiated and coordinated the project. All authors read and approved the final manuscript.

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References

1. Bundesanstalt für Arbeitsschutz und Arbeitsmedizin [BAuA], Bundesministerium für Arbeit und Soziales [BMAS], editors. [Safety and Health at Work: Report of occupational accident prevention 2018] Sicherheit und Gesundheit bei der Arbeit – Berichtsjahr 2018: Unfallverhütungsbericht Arbeit. 2nd edition. Dortmund/Berlin/Dresden: Bundesministerium für Arbeit und Soziales/Bundesanstalt für Arbeitsschutz und Arbeitsmedizin; 2020.
2. Council of the European Communities. COUNCIL DIRECTIVE of 29 May 1990 on the minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers (fourth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC). 1990.

3. Dagmar Lühmann, Tatjana Burkhardt-Hammer, Susanne Stoll, Heiner Raspe. Prävention rezidivierender Rückenschmerzen - Präventionsmaßnahmen in der Arbeitsplatzumgebung [Prevention of Recurrent Back Pain - Prevention Measures at the Work Place Environment]. Schriftenreihe Health Technology Assessment. 2006;38.
4. Reddell CR, Congleton JJ, Dale Huchingson R, Montgomery JF. An evaluation of a weightlifting belt and back injury prevention training class for airline baggage handlers. Appl Ergon. 1992;23:319–29.
5. van Poppel MN, Koes BW, van der Ploeg T, Smid T, Bouter LM. Lumbar supports and education for the prevention of low back pain in industry: a randomized controlled trial. JAMA. 1998;279:1789–94.
6. van Poppel MNM, Hooftman WE, Koes BW. An update of a systematic review of controlled clinical trials on the primary prevention of back pain at the workplace. Occup Med (Lond). 2004;54:345–52.
7. Maher CG. A systematic review of workplace interventions to prevent low back pain. Aust J Physiother. 2000;46:259–69.
8. Tveito TH, Hysing M, Eriksen HR. Low back pain interventions at the workplace: a systematic literature review. Occup Med (Lond). 2004;54:3–13.
9. Van Eerd D, Munhall C, Irvin E, Rempel D, Brewer S, van der Beek AJ, et al. Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence. Occup Environ Med. 2016;73:62–70.
10. Hogan DAM, Greiner BA, O'Sullivan L. The effect of manual handling training on achieving training transfer, employee's behaviour change and subsequent reduction of work-related musculoskeletal disorders: a systematic review. Ergonomics. 2014;57:93–107.
11. International Organisation for Standardization. Ergonomics: application document for International Standards on manual handling (ISO 11228-1, ISO 11228-2 and ISO 11228-3) and evaluation of static working postures (ISO 11226). Genève: ISO; 2014.
12. DIN EN 1005-4. DIN EN 1005-4:2009-01, Sicherheit von Maschinen_- Menschliche körperliche Leistung_- Teil_4: Bewertung von Körperhaltungen und Bewegungen bei der Arbeit an Maschinen; Deutsche Version EN_1005-4:2005+A1:2008 [Safety Of Machinery - Human Physical Performance - Part 4: Evaluation Of Working Postures And Movements In Relation To Machinery; German Version EN1005-4:2005+A1:2008]. Beuth Verlag GmbH; 2009.
13. Crawford JO. The Nordic Musculoskeletal Questionnaire. Occup Med (Lond). 2007;57:300–1.
14. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Applied Ergonomics. 1987;18:233–7.
15. Bundesanstalt Für Arbeitsschutz Und Arbeitsmedizin (BAuA), editor. MEGAPHYS - Mehrstufige Gefährdungsanalyse physischer Belastungen am Arbeitsplatz [MEGAPHYS - Multi Step Risk Assessment of Physical Loads at the Work Place]. 2019;1:986.
16. Bundesanstalt Für Arbeitsschutz Und Arbeitsmedizin (BAuA). Gefährdungsbeurteilung bei physischer Belastung - die neuen Leitmerkmalmethoden (LMM): Kurzfassung [Risk Assessment of Physical

Load - The New Key Indicator Methods (KIM): Short Form]. 2019. https://doi.org/10.21934/BAUA:BERICHT20191203.

17. Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAuA), editor. Erweiterte Leitmerkmalmethoden (LMM-E): Algorithmen für Interpolation und Zusammenfassung [Extended Key Indicator Methods (KIM-E): Algorithms for Interpolation and Summary]. 2020. https://doi.org/10.21934/BAUA:FOKUS20200414.
18. Federal Institute for Occupational Safety and Health (BAuA). Guideline for the Key Indicator Method for assessing and designing physical workloads with respect to Whole-Body Forces (KIM-BF). 2019.
19. Federal Institute for Occupational Safety and Health (BAuA), editor. Key Indicator Method for assessing and designing physical workloads with respect to manual Lifting, Holding and Carrying of loads ≥ 3 kg (KIM-LHC). 2019.
20. Federal Institute for Occupational Safety and Health (BAuA), editor. Key Indicator Method for assessing and designing physical workloads with respect to manual Pushing and Pulling of loads (KIM-PP). 2019.
21. Ebener M, Hasselhorn HM. Validation of Short Measures of Work Ability for Research and Employee Surveys. Int J Environ Res Public Health. 2019;16.
22. Twisk J, Proper K. Evaluation of the results of a randomized controlled trial: how to define changes between baseline and follow-up. JClinEpidemiol. 2004;57:223–8.
23. Fox J. Applied regression analysis and generalized linear models. Third Edition. Los Angeles: SAGE; 2016.
24. Buuren S van. Flexible imputation of missing data. Second edition. Boca Raton: CRC Press; 2018.
25. R Core Team. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing; 2018.
26. Hadley Wickham, Carson Sievert. ggplot2: Elegant graphics for data analysis. 2nd edition. Cham: Springer International Publishing; 2016.
27. Wilke CO. cowplot: Streamlined plot theme and plot annotations for “ggplot2.” manual. 2020.
28. Fox J, Weisberg S. An R companion to applied regression. 3rd edition. Thousand Oaks CA: Sage; 2019.
29. Canty A, Ripley BD. boot: Bootstrap r (s-plus) functions. manual. 2020.
30. Davison AC, Hinkley DV. Bootstrap methods and their applications. Cambridge: Cambridge University Press; 1997.
31. Buuren S van, Groothuis-Oudshoorn K. mice: Multivariate Imputation by Chained Equations in R. Journal of Statistical Software. 2011;45:1–67.
32. World Medical Association (WMA). WMA - The World Medical Association-WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects. 2013.
33. Hofmann W, Latza U, Terschüren C. Leitlinien und Empfehlungen zur Sicherung von Guter Epidemiologischer Praxis (GEP) - überarbeitete Fassung nach Evaluation. Gesundheitswesen.

2005;67:217–25.

34. International Commission on Occupat, editor. INTERNATIONAL CODE OF ETHICS FOR OCCUPATIONAL HEALTH PROFESSIONALS. 3rd edition. Rom; 2014.
35. Bundesministeriumg für Justiz. BDSG - Bundesdatenschutzgesetz. 2018.
36. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) (Text with EEA relevance). 2016.

Figures

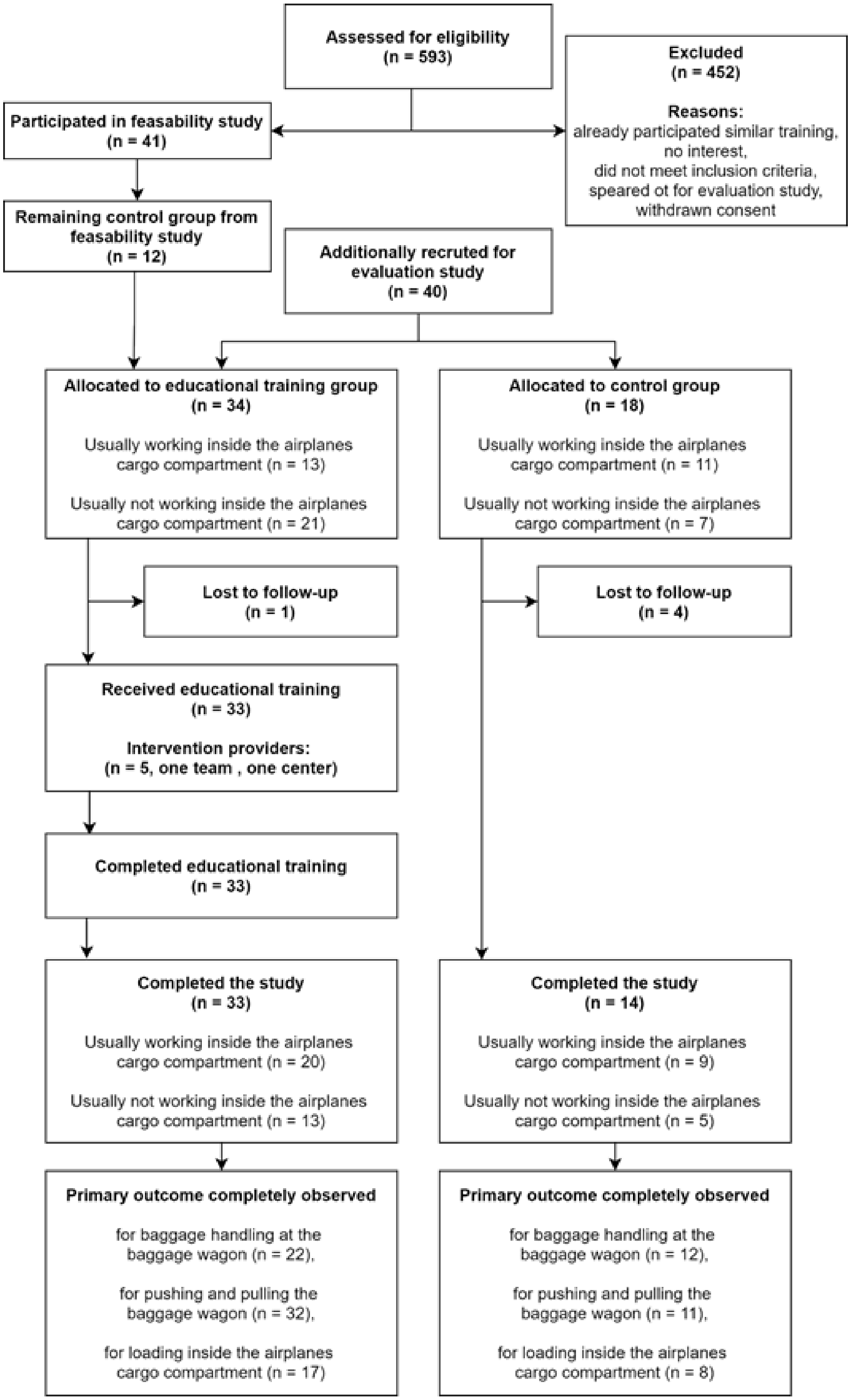

Figure 1

Flow-Chart of the study participants.

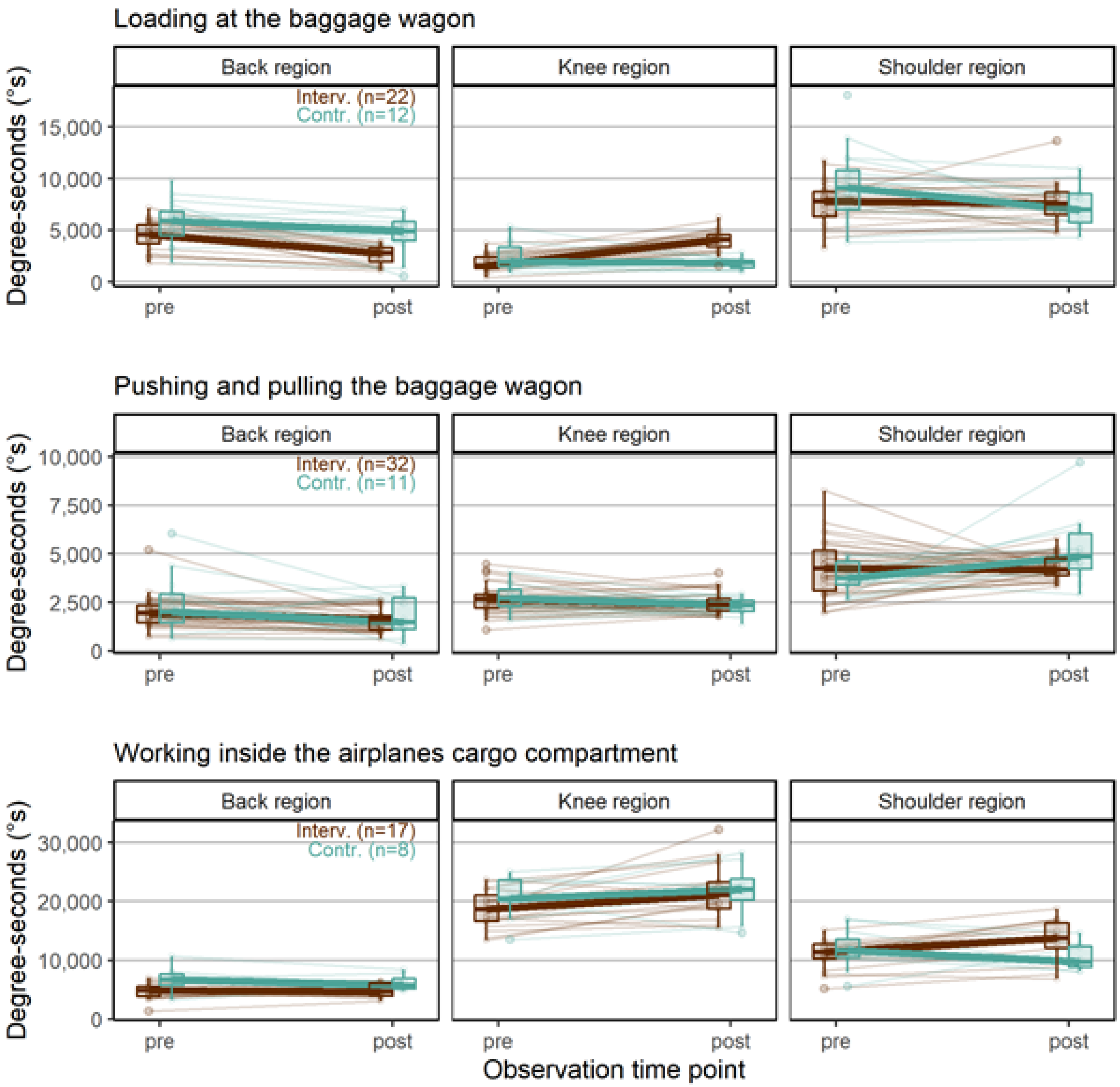

Figure 2

Weighted sum parameters for the load of the back, knees and shoulders in three working scenarios (interventions brown, controls blue).