The body height as an input parameter for a capability-based order assignment in manual order picking

Tim STEINEBACH[1], Julia WENZEL[2], Jurij WAKULA[1], Ralf ELBERT[2]

[1] *Institute for Ergonomics & Human Factors, Technical University Darmstadt Otto-Berndt-Straße 2, 64287 Darmstadt, Germany*
[2] *Chair of Management and Logistics, Technical University Darmstadt Hochschulstraße 1, 64289 Darmstadt, Germany*

Abstract. According to the literature, manual order picking causes high physical workloads. In addition, specific capabilities and the constitution of individual employees are not taken into account when assigning orders to a picker. In this paper, the influence of body height on the workload of pickers during picking processes from different picking heights is analysed in order to be able to assign picking orders to specific employees, if the storage location is known (e.g. in a rack). For this purpose, laboratory experiments were conducted with eleven test subjects. The postures adopted by the test subjects were recorded by means of a video camera and an IMU motion capture system and independently evaluated by two analysts using the "MultipLa" screening tool. While smaller persons tend to have more favorable postures at low rack heights (< 80 cm), they have less favorable postures at upper rack heights (> 140 cm) compared to larger persons.

Keywords: order picking, capability-based order assignment, body height, posture

1. Motivation

Despite advancing automation, person-to-goods order picking is still characterized by a high proportion of manual material handling (Michel 2017, Grosse et al. 2015). The performed manual tasks, e.g. picking of heavy articles combined with unfavourable postures, carries a high risk of developing musculoskeletal diseases. Lower back pain in particular has proven to be a very common health risk (Gajšek et al. 2020), which can lead to long sick leave periods of order pickers. In addition, employees show high deviations in their individual performance, which can be caused by differences in constitution (e.g., gender, height) or disposition (e.g., age, health) (Luczak 1989; Ilmarinen & Tempel 2001). However, if human factors are considered in optimization problems in manual order picking at all, then as parameters with constant characteristics and capabilities (Grosse et al. 2015).

In the "AufKomm" project, which is funded by HOLM (House of Logistics and Mobility), the potential of a capability-based order assignment to specific employees for picking activities is to be evaluated. Such an assignment strategy bundles incoming orders and distributes them among the employees in such a way that, with a constant overall workload, individual order pickers are deployed according to their characteristics and capabilities and thus experience less individual strain compared to a random order assignment.

In the literature, the assignment of orders to specific employees is usually random or on a "first-free" basis. Individual characteristics or performance have rarely been considered in this context so far.

A first approach comes from Matusiak et al. (2017). The authors evaluate different picking skills of warehouse employees, such as the ability to lift heavy or large-volume items or to reach into high or low rack levels. Based on this information, a heuristic is developed which assigns orders to employees with the goal of minimizing process time. In comparison with "first-free" order assignment, a reduction of up to 12% of the lead time can be achieved. However, the physical workload or the strain on the operator is not taken into account.

Furthermore, Calzavara et al. (2018) determine individual fatigue and rest allowance with the help of heart rate monitoring to be able to schedule orders for specific order pickers. The authors demonstrated, that taking the individual physiological parameters into account leads to a productivity improvement.

This article focuses on determining the influence of the body height of individual operators on the postures adopted during picking operations of varying load weights and picking heights.

2. Methodology

To evaluate postures in manual material handling, the Multiple Loads Tool ("MultipLa", Schaub et al. 2012) is used. Here, using a classification guide (identical to that of the Key Indicator Method Lifting, Holding, Carrying; BAuA, 2001), posture rating points are determined according to certain characteristics of the posture. The posture rating can be selected between one and eight points and depends, for example, on the degree of trunk flexion or torsion, the handling of the load in a position close to or far from the body. Also, the handling of the load below or above shoulder height is an important characteristic for evaluating the posture. The adapted posture must be rated during load reception and release separately and averaged afterwards.

In order to be able to determine the influence of the body height on the rating of the posture during various picking processes, picking activities were simulated in the IAD laboratory. Cardboard boxes with the dimensions 30 x 20 x 20 cm were filled with three different load weights (0.5 kg, 5 kg, 10 kg). The filled boxes' centre of gravity is to be regarded as stable. The test subjects started with a series of exercises in order to become familiar with the procedure. The boxes were then removed one after the other from shelves with ten different rack heights at a distance of 20 cm (0-180 cm) and transferred to a picking trolley. It should be noted that the actual position of the hand is a few cm above the corresponding rack height. The picking process always took place with both hands. The two influencing variables “rack height” and “load weight” were varied in a full factorial test design, so that a total of 30 picking processes were carried out by the test subjects in a permuted sequence.

The eleven subjects had an average height of 175.9 ± 9.7 cm (min = 160 cm; max = 192 cm). Seven of the test persons were male and four female - two of them already had previous picking experience.

The test subjects were equipped with an IMU motion capture system (TEA Captiv L7000 Premier) during manual material handling and filmed with video cameras to determine the postures adopted and the corresponding MultipLa posture ratings based on the data collected. The posture rating points during load reception were independently evaluated by two trained analysts and averaged in case of deviations. Since the load release is always carried out to a handcart with constant height, it is not considered in the following results.

3. Results

3.1 Mean posture ratings across all test subjects

Figure 1 shows the average postural rating points of all test subjects and both analysts for each rack height when handling the three different load weights. High postural rating points are mainly to find in low and very high rack areas.

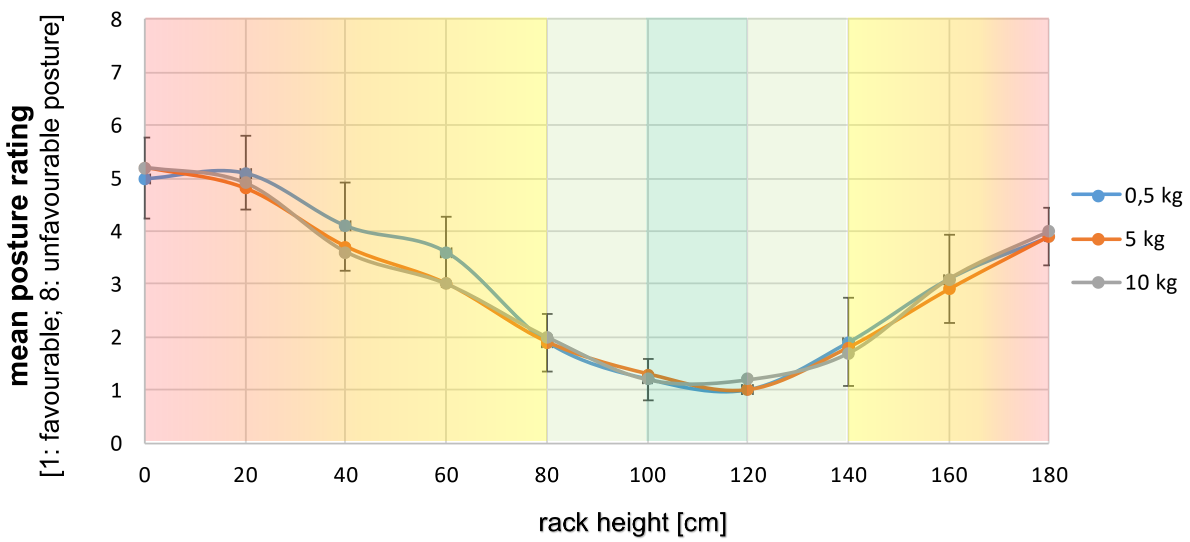

Figure 1. *Mean posture ratings across all test subjects and three load weights*

The loads 0.5 kg, 5 kg and 10 kg have almost congruent courses in the individual rack heights, shown in Figure 1. The only difference is slightly lower average posture ratings (approx. 0.5 rating points) for the rack heights of 20 - 60 cm for the two heavier load weights.

3.2 Posture rating points as a function of body height: regression analysis

Then for each rack height the posture ratings were plotted in a single diagram as a function of body height. A linear regression line could thus be calculated for each rack height. With the regression line a statement about the relationship between body height and the posture rating at a certain rack height could be derived. Figure 2 shows regression lines for four selected rack heights (20 cm, 60 cm, 100 cm and 140 cm) and the corresponding equation.

The regression lines have a positive gradient for low rack heights and a negative gradient for higher rack heights. In contrast to this, the gradient of the regression lines for lifting at medium rack heights (100 cm and 120 cm) is close to zero.

In addition, figure 3 also shows the corresponding correlation coefficients for all rack heights and load weights.

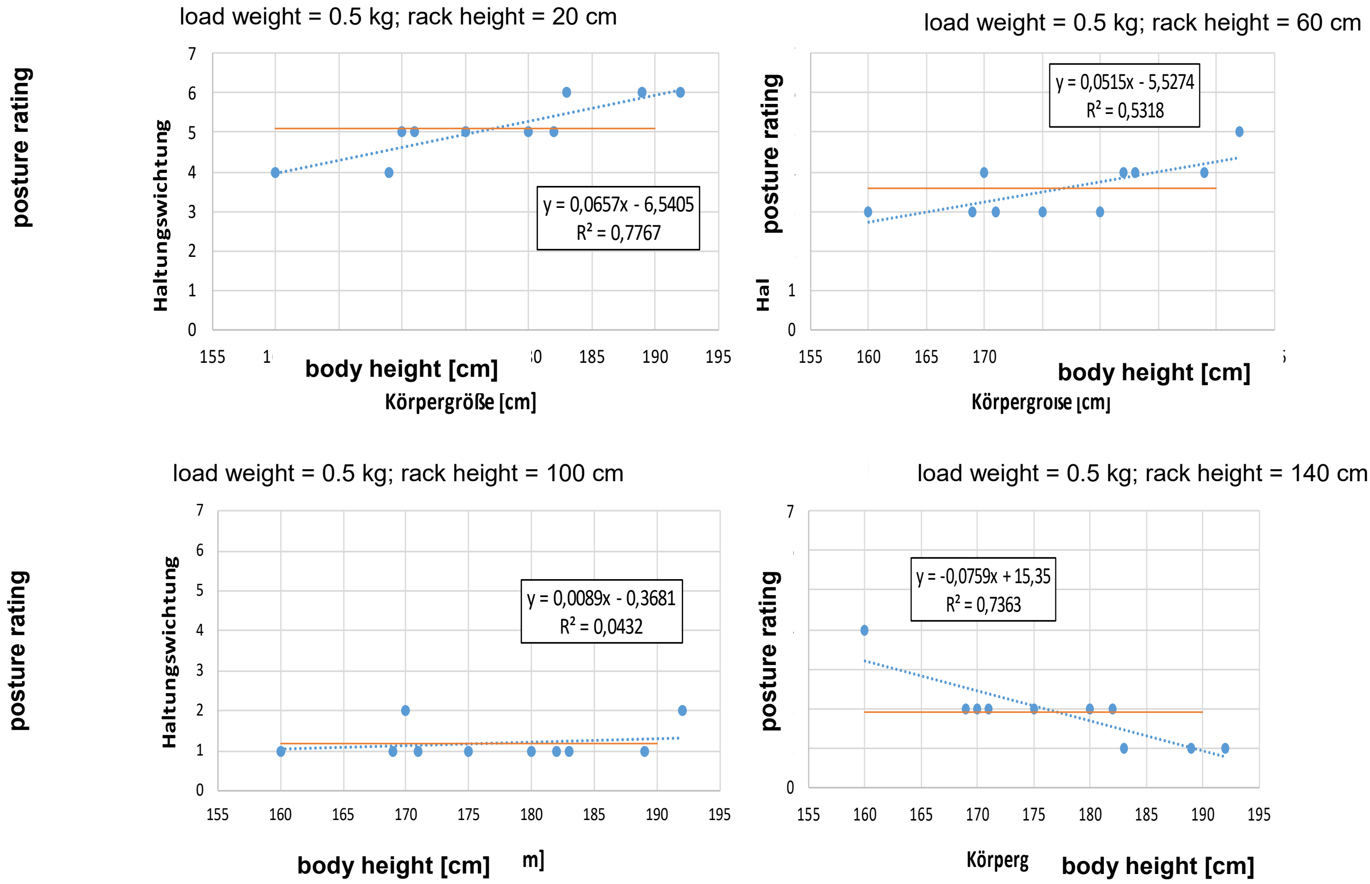

Figure 2. *Regression lines of posture rating points as a function of height (n = 11) with a load weight = 0.5 kg on the rack heights 20 cm, 60 cm, 100 cm and 140 cm*

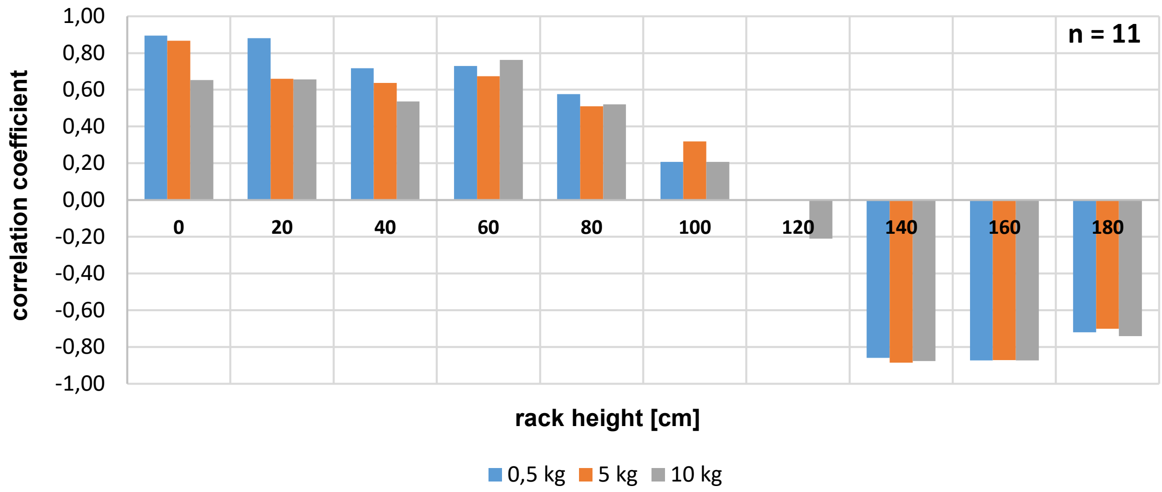

Figure 3. *Correlation coefficients as a function of the rack height (n = 11) for different load weights*

4. Discussion

First of all, it should be noted that, as expected, the optimum area for removal of articles from a shelf is between 100 and 120 cm in rack height, regardless of the body height of the operator. Here, the corresponding posture rating points (see figure 1) are very low, which is in line with the recommendation of the optimum removal height of 110 cm of the standard VDI 3657. More unfavourable posture ratings are achieved at rack heights lower than 80 cm (trunk flexion) or higher than 140 cm (work at or above shoulder/ head height). Shelf locations with a rack height of less than 40 cm are particularly critical - here the posture rating points partially increases to values of five or more.

Meanwhile, the influence of load weight on the posture is quite small. Only at very low rack heights, the test subjects seem to tend to adopt somewhat more favourable postures with higher load weights (5 kg and 10 kg). A possible explanation could be that this allows a more stable and comfortable lifting of heavy loads.

Looking at the regression functions (figure 2), it becomes clear that posture ratings depend on body height of the operators. While smaller persons tend to have lower postural ratings at low rack heights, they have higher postural ratings at upper rack heights compared to taller persons. This relationship can be seen by the correlation coefficients in figure 3, as well. With $r > 0.5$, all coefficients except those of the middle rack levels (100 cm and 120 cm) have a large effect size (Cohen, 1992). The strength of the correlation tends to decrease slightly from the ground towards medium rack heights.

In contrast, hardly any dependencies between posture rating and body height can be observed at medium rack levels - the corresponding correlation coefficients are also very low. Here it seems that favourable postures are possible for all order pickers, regardless of load weight and rack height. Similarly, this relationship seems to decrease slightly at the height of 180 cm, as almost all test subjects have to work at or above shoulder height. The gradient of the corresponding regression line is significantly flatter than at 160 cm (e.g. with load weight of 0.5 kg: $\beta = -0.0773$ at 160 cm vs. $\beta = -0.0498$ at 180 cm). At this rack level, small persons have difficulty reaching the cardboard boxes at all.

These relationships can be used to assign orders to specific operators with knowledge of the storage location height. In concrete terms, tall order pickers would tend to be assigned articles from upper shelf levels and small order pickers would tend to be assigned articles from lower shelf levels. For this purpose, the determined regression functions can be used directly in a mathematical optimisation. Due to the lower resulting posture ratings there is the potential of less physical workload for order pickers when applying the capability-based order assignment in practice.

The study is subject to a couple of limitations. Despite the support of motion capture data, the evaluation of postures by the rather rough classification guide in MultipLa is subjective and dependent on the analyst. Furthermore, the number of test persons is relatively small and only two persons had experience in order picking - this could have an influence on the collected movement patterns. Furthermore, the influence of gender on posture was not investigated.

5. Resume

In the study presented, optimal rack heights could be identified with respect to postures adopted by the operators. Furthermore, the relationship between body height and posture ratings of the screening tool MultipLa was mathematically described using regression functions and correlation coefficients.

The results can be used to incorporate the physical constitutional characteristic "body height" into a capability-based order assignment in manual order picking. In a next step of this HOLM project, further capability indicators (age, gender) are to be determined and quantified to be converted into heuristics for order assignment. Subsequently, the assignment heuristics can be analysed in a computer simulation with the software Anylogic.

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6. References

Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (2001) Leitmerkmalmethode zur Beurteilung von Heben, Halten und Tragen (Formblatt).

Calzavara M, Persona A, Sgarbossa F, Visentin V (2019) A model for rest allowance estimation to improve tasks assignment to operators. International Journal of Production Research 57(3):948-962.

Cohen J (1992) A power primer. Psychological bulletin, 112(1), 155.

Gajšek B, Dukić G, Butlewski M, Opetuk T, Cajner H, Kač SM (2020) The impact of the applied technology on health and productivity in manual “picker-to-part” systems. Work 65:525-536.

Grosse EH, Glock CH, Jaber MY, Neumann WP (2015) Incorporating human factors in order picking planning models: framework and research opportunities. International Journal of Production Research 53(3):695-717.

Ilmarinen J, Tempel J (2002) Arbeitsfähigkeit 2010: was können wir tun, damit Sie gesund bleiben?. VSA-Verlag.

Luczak H (1989) Wesen menschlicher Leistung. Arbeitsgestaltung in Produktion und Verwaltung. Wirtschaftsverlag Bachem, Köln, 39-64.

Matusiak M, de Koster R, Saarinen J (2017) Utilizing individual picker skills to improve order batching in a warehouse. European Journal of Operational Research, 263(3):888-899.

Michel R (2017) 2017 Warehouse/DC Operations Survey. In the thick of e-commerce adjustments. Logistics Management, 56 (11):52-58.

Schaub K, Steinberg U, Bierwirth M, Kugler M, Kaltbeitzel J, Bruder, R. (2012) MultipLa – a tool for the combined overall estimation of various types of manual handling tasks. Work, 41:4433-4435.

VDI 3657 (1993). Verein Deutscher Ingenieure (VDI) - VDI 3657: Ergonomische Gestaltung von Kommissionierarbeitsplätzen. Beuth Verlag, Berlin.

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