

BMJ Open Postural sway, working years and BMI in healthy truck drivers: an observational study

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ABSTRACT

Objectives The following study analyses the influence of risk factors among the occupational group of truck drivers on postural control and body mass index (BMI).

Design Observational study.

Setting One motorway station close to several highways in Germany.

Participants 180 truck drivers (177 male/3 female), aged 21–65 years old, took part in this study.

Outcome measures Postural control was examined using a pressure plate. In order to examine the influence of body weight (BMI) and working years on postural control, subjects were divided into samples of five and three groups, respectively. Furthermore, it was evaluated whether the subjects suffered from back pain. For data analysis, the Kruskal-Wallis test was used as the data were not normally distributed. Once the p value of the Kruskal-Wallis test was $p \leq 0.05$, the Conover-Iman comparison and afterwards the Bonferroni-Holm correction were used. The significance level was set at $\alpha \leq 0.05$.

Results Regarding the number of working years, a significant increase of frontal ($p \leq 0.04$) and sagittal ($p \leq 0.001$) sway were observed. The correlation of the five BMI groups with the number of working years demonstrates that an increase of the working years leads to an increase of BMI ($p \leq 0.03$). Furthermore, the majority of truck drivers participating in this study suffered from back pain (61.7%).

Conclusions BMI and musculoskeletal impairment are indicators of health risk factors. In this study, it is shown that an increasing number of working years and an increasing BMI lead to a decrease in frontal and sagittal postural sway. In addition, the number of working years correlates with body weight and back pain.

INTRODUCTION

Human posture and stability are influenced and controlled by a large number of endogenous systems of the body to keep up its stability.¹ All biological systems permanently try to minimise energetic costs by maintaining an upright posture. One of these systems is the muscular-skeletal system. The body weight is evenly distributed on both feet with the least muscular activity and the centre of mass is placed over the centre of pressure (COP). Equal distribution of body weight minimises

Strengths and limitations of this study

- One strength of this study is the large number of participants.
- Another is the separate analysis according to body mass index, working years and back pain.
- One limitation of the study is the measuring of the postural control outside the driver's cabin.
- Furthermore, external influences such as the specification seats classification and the seat cushioning were not taken into account.

skeletal pressure.^{2–6} If this system is impaired, disturbed gait patterns and an increased risk of falling are observed, for example, in patients with Parkinson's disease or cerebral palsy.^{7–8} Measuring COP or gait patterns in people with Parkinson's disease or cerebral palsy has been used as an early indicator for musculoskeletal dysfunction.

Furthermore, there are neuronal systems like the visual and vestibular system which interact with each other.⁹ This way a finely tuned system is formed, which is capable of stabilising the posture during all movement tasks. If necessary, counter-regulatory actions might be taken.

Human posture is influenced by biomechanical data of the proprioceptors and by environmental factors.¹⁰ However, the physiological postural balance can be disturbed by means of several external influences and may lead to a non-physiological foot pressure and an increased pressure on the rearfoot and midfoot.¹¹ The most important causes are obesity and lack of exercise.^{11–12} Birtane *et al*¹¹ assumed that obesity leads to a shift of the body's centre of gravity resulting in an excessive loading of some parts of the foot, especially the rearfoot and midfoot. This dysfunctional loading of the feet influences the compensation mechanisms of postural control so that back muscles, on spinal and neuronal level, eyes and the vestibular system have to compensate accordingly.



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There are several studies comparing the range of body sway between normal weight subjects and overweight subjects. Colné *et al*¹³ states that there is an increase of mediolateral sway within the group of overweight subjects compared with the body sway within the group of normal weight subjects. In addition, Hue *et al*¹⁴ have shown that increasing obesity correlates with a shift of the body's centre of gravity towards the frontal direction. This shift directly influences the postural control and foot loading. Changes in postural control with increasing age have been found by Røgind *et al*.¹⁵

Postural control is also influenced by monotonous sitting over a long period of time. Szeto *et al*¹⁶ examined this with a group of bureau employees and concluded that people who spend a lot of time sitting in front of a computer or a desk more often suffer from back pain.

Merely 20% of truck drivers interviewed by Ellinghaus and Steinbrecher¹⁷ did not have any physical discomfort at all while driving. About 60% complained of occasional or frequent back pain, muscle pain and/or joint pain. With increasing age, a growth of these disorders could be observed.¹⁷ Gawda *et al*¹⁸ observed an increase of frontal and sagittal sway as an effect of back pain.

Truck drivers are an occupational group evidentially suffering from obesity, back pain and a lack of exercise while spending a lot of hours in a sitting position.^{19–21}

Due to their profession they spend most of the working time sitting in a forced position in their trucks. In addition, they normally have less time for exercise or regular sport activities beside their job. Moreover, truck drivers are mostly used to an unhealthy and fatty diet²² as a consequence of which obesity is a common disease among truck drivers.^{21 23–25}

The fact that truck driving can cause damage to health has already been shown in several studies.

A number of risk factors, such as overweight or rather obesity, long periods of sitting and lack of exercise are often found in truck drivers. These factors may damage the musculoskeletal system and result in both back pain and/or impaired compensational movements. These may be quantified by measuring body posture or postural sway.

Therefore, this study examines the effects of obesity, long monotonous working conditions in a forced position and back pain in the professional group of truck drivers on the postural sway. The working hypotheses of this study are as follows:

1. A rising number of working years leads to declining postural sway by increased frontal and sagittal sway.
2. Obesity is an independent factor for declining postural sway in truck drivers.
3. Participants reporting back pain also have deviating postural sway and weight distribution.

METHODS

Subjects

One hundred and eighty healthy, randomly chosen truck drivers (177 male/3 female) took part in this study, age

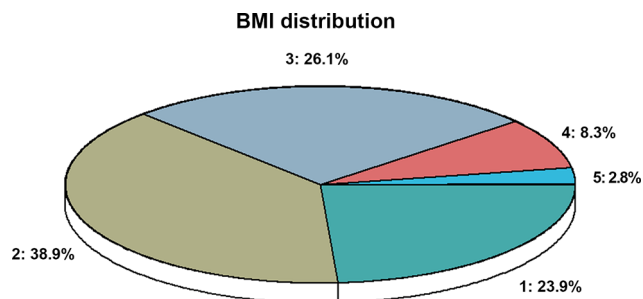


Figure 1 BMI distribution: 1 (normal weight) BMI 18.5–24 kg/m², 2 (pre-obesity) BMI 25–29.9 kg/m², 3 (obesity I°) BMI 30–34.9 kg/m², 4 (obesity II°) BMI 35–39.9 kg/m², 5 (obesity III°) BMI >40 kg/m². BMI, body mass index.

ranging from 21 to 65 years (average age 46.5±10.65 years). Participants had up to 45 years of work experience and worked an average of 11 hours daily. The average BMI of the subjects was 29.1±5.6 kg/m².

Only healthy individuals without any diseases in need of treatment such as acute infections were considered to participate in this study.

Subjects were divided into three groups with almost the same sample size based on the number of working years (group 1: working experience of up to 12 years, group 2: working experience between 13 and 25 years and group 3: working experience >25 years).

Subjects were also grouped according to the BMI classification of the WHO²⁶: group 1 (normal weight), group 2 (pre-obese), group 3 (obesity °1), group 4 (obesity °2) and group 5 (obesity °3) (figure 1).

Furthermore, subjects had to complete a questionnaire (see online supplementary file 1) in order to differentiate between individuals with and without back pain. In addition, the occurrence of back pain (daily, weekly, monthly, never) was evaluated. Finally, subjects had to declare whether the back pain was being treated by a doctor.

This study was approved by the ethics research committee involving human subjects of the Goethe-University (134/14) in Frankfurt am Main, Germany.

Measurement system

For pressure measurement, the GP Multisens plate (GeBioM, Münster, Germany) was used. The measurement plate is 45 cm x 55 cm large with a measuring surface of 38.5 cm x 38.5 cm on which 2304 resistance sensors are installed (1.25 sensors per cm²). The sampling is 200 Hz

Table 1 Mean values and SD of age, height, weight and BMI grouped by working years

Working years	Mean age (years)	Mean height (cm)	Mean weight (kg)	Mean BMI (kg/m ²)
Group 1	34.7±9.0	179±7.5	91.3±22.9	28.3±6.0
Group 2	46.35±7.1	178±6.4	91.15±21.1	28.64±5.9
Group 3	55.8±4.3	179.2±6.9	97.6±16.2	30.4±4.8

BMI, body mass index.

**Table 2** Mean values and SD of age, height, weight and BMI grouped by BMI

BMI groups	Mean age (years)	Mean height (cm)	Mean weight (kg)	Mean BMI (kg/m ²)
I	42.8±4.0	176.7±7.3	72.1±8.5	23.0±1.6
II	47.7±10.6	179.4±6.2	88.8±7.5	27.6±1.4
III	47.9±9.0	179.2±7.8	104.9±11.2	32.6±1.8
IV	46.8±11.9	179.0±5.3	119.7±7.7	36.9±1.5
V	48.4±13.3	179.0±6.0	155.0±27.3	48.2±6.6

BMI, body mass index.

and the sensors work with a precision of ±5%. The pressure is measured in Pascal (force/area).

Data collection

First of all, the participants were weighed and their height was measured in order to calculate their BMI.

Afterwards the participants had to stand barefoot on the measuring surface of a pressure measurement plate. They were asked to maintain their habitual foot position. Each measurement of the postural sway took 30s. The mean value of five independent repetitions was calculated.

Evaluation parameters

The following parameters of postural sway were considered in this study: (1) maximal excursion of frontal (forward–backward) and sagittal (mediolateral) sway (mm), (2) percentage distribution of body weight on each foot section (forefoot left, forefoot right, rearfoot left, rearfoot right), (3) total percentage body weight distribution on forefoot and rearfoot, (4) percentage body weight distribution between left and right foot.

Data analysis

The recorded data were analysed with the BIAS software (V. 10.12, GeBioM, Münster, Germany). The assumption of normality was tested using the Kolmogorov-Smirnov-Lilliefors test. As the data were not normally distributed, the Kruskal-Wallis test was used for all group

Table 3 Evaluation parameters of postural sway

	Median	Percentile (1st/3rd)
Frontal sway (mm)	9.4	6.4/13.2
Sagittal sway (mm)	16.4	12.6/20.5
Forefoot left (%)	19.7	16.8/22.4
Forefoot right (%)	20.8	17.7/23.8
Rearfoot right (%)	31.2	27.4/36.4
Rearfoot left	27.3	24.1/30.8
Left foot (%)	46.9	42.2/52.2
Right foot (%)	53.0	47.8/57.8
Forefoot (%)	40.9	36.1/44.4
Rearfoot (%)	59.0	55.6/63.7

differences. If the p value of the Kruskal-Wallis test was $p \leq 0.05$, the Conover-Iman comparison and afterwards the Bonferroni-Holm correction was used. The significance level was $p \leq 0.05$.

RESULTS

The participating truck drivers were between 21 and 65 years of age (average age 46.5±10.65 years). Their work experience ranged from 1 to 45 years (average work experience 21±11.65 years) and they worked a mean 11 hours per day. The BMI of the subjects was on average 29.1±5.6 kg/m² (median 28.4 kg/m²; min. 18.94 kg/m², max. 56.74 kg/m²).

Subjects were divided into three groups according to their working years, so that subjects in group 1 with little experience have a mean work experience of 6.3±3.1 years and a mean age of 34.7±9 years. Subjects of group 2 show a mean work experience of 20±4.5 years and a mean age of 46.3±7.1 years. In group 3 (most experienced workers), there is a mean work experience of 34.35±4.3 years with a mean age of 55.8±4.3 years.

According to the group distribution of the BMI classification of the WHO,²⁶ 29.9% belong to group 1 (normal weight, BMI 18.5–24.9 kg/m²) and 38.9% of the subjects to group 2 (pre-obese) with a BMI of 25–29.9 kg/m². Group 3 consists of 26.1% (obesity °1, BMI 30–34.9 kg/m²) and group 4 of 8.3% (obesity °2, BMI 35–39.9 kg/m²). 2.8% have a BMI of >40 kg/m² (obesity °3) and form group 5.

Table 1 includes mean values and SD of age, height, weight and BMI for the participants grouped by working years.

In table 2, the same parameters are illustrated for the participants according to BMI.

Table 3 shows the median and the percentiles (1st/3rd) of all parameters for all subjects. The median of frontal sway is 9.4 mm, the first percentile 6.4 mm and the third percentile 13.2 mm. The median of sagittal sway is 16.4 mm (12.6 mm/0.5 mm).

The median of percentage body weight distribution is highest on the right rearfoot with 31.2% (27.4%/36.4%), while the median of the right forefoot has a percentage of 20.8% (17.7%/23.8%). For the left foot, the following percentages for the median can be stated: the rearfoot has 27.3% (24.1%/30.8%) and the forefoot has 19.7% (16.8%/22.4%). The comparison of the left and right side shows a higher percentage distribution on the right side with a median of 53.0% and percentiles of 47.8% and 57.8% (left foot: median=47.0%; 1st=42.2%; 3rd=52.2%). On average, the rearfoot is more loaded than the forefoot with 59.0% to 40.9% (rearfoot: 55.6%/63.7%; forefoot: 36.1%/44.4%).

Group comparison due to working years

Table 3 shows the median and the percentiles (1st/3rd) of all parameters for all subjects. The median of frontal sway is 9.4 mm, the first percentile 6.4 mm and the

Table 4 Evaluation parameters and p values due to working years groups and BMI groups

(A) Evaluation parameters due to working year groups		Group 1			Group 2			Group 3		
Working years	p Value	Median	Percentile	Median	Percentile	Median	Percentile	Median	Percentile	
Frontal sway (mm)	0.04	8.6	6.2/13.8	8.2	6.2/11.2	10.5	7.6/15.5			
Sagittal sway (mm)	0.001	15.0	10.4/18.4	14.8	12.4/18.8	17.4	14.0/22.9			
Forefoot left (%)	0.18	19.6	17.4/22.2	18.8	16.8/22.0	20.5	15.7/23.7			
Forefoot right (%)	0.11	20.2	16.4/22.7	20.4	17.0/23.8.0	21.4	18.9/24.6			
Rear foot right (%)	0.79	30.8	27.4/37.0	32.8	27.2/36.4	30.8	27.7/35.4			
Rear foot left (%)	0.33	27.7	24.2/32.4	28.0	24.4/30.8	26.8	22.9/29.4			
Left foot (%)	0.15	48.8	44.8/52.6	47.0	41.6/52.6	46.4	41.5/50.3			
Right foot (%)	0.18	51.2	47.4/55.2	53.0	47.4/58.4	53.6	49.7/58.4			
Forefoot (%)	0.07	40.4	35.6/43.6	40.4	36.2/43.0	42.5	37.1/46.2			
Rearfoot (%)	0.07	59.6	56.2/64.4	59.6	57.0/63.5	57.5	53.7/62.8			

(B) Evaluation parameters due to BMI groups		Group I			Group II			Group III			Group IV			Group V		
BMI groups	p Value	Median	Percentile	Median	Percentile	Median	Percentile	Median	Percentile	Median	Percentile	Median	Percentile	Median	Percentile	
Frontal sway (mm)	0.04	7.6	5.2/12.4	9.6	6.8/11.8	8.8	6.4/15.4	11.8	7.6/18.2	10.0	8.1/13.6					
Sagittal sway (mm)	0.01	13.0	10.0/18.0	16.4	12.6/18.8	17.2	4.0/21.0	20.2	16.2/24.0	16.8	15.2/23.4					
Forefoot left (%)	0.49	19.6	16.4/22.8	19.3	16.7/22.0	20.4	17.0/23.4	19.8	16.4/23.4	18.8	17.4/22.9					
Forefoot right (%)	0.46	16.6	18.2/23.8	20.3	16.8/24.6	21.4	18.0/23.4	21.4	20.2/24.6	20.6	17.4/23.0					
Rearfoot right (%)	0.94	32.8	27.8/36.4	31.5	28.8/35.7	30.8	27.0/37.4	30.5	27.0/35.0	32.0	28.1/43.6					
Rearfoot left (%)	0.08	27.6	24.2/30.8	27.3	24.4/31.7	27.2	23.0/30.0	27.0	23.0/30.6	26.8	19.7/28.9					
Left foot (%)	0.35	46.6	42.0/52.2	46.8	43.1/52.2	47.2	41.4/53.6	46.2	41.6/52.2	48.4	37.4/50.4					
Right foot (%)	0.37	53.4	47.8/58.0	53.1	47.8/56.8	52.8	46.4/58.6	53.8	47.8/58.4	51.6	49.4/65.4					
Forefoot (%)	0.17	39.6	34.8/44.6	40.3	34.8/43.3	41.4	38.2/45.0	41.5	28.6/52.6	40.0	36.5/43.4					
Rearfoot (%)	0.48	60.4	55.4/65.2	59.3	56.7/65.0	58.6	55.0/61.8	58.5	52.8/59.4	60.0	56.6/63.5					

The bold values have a significant difference ($p < 0.05$).

This table contains the Kruskal-Wallis test p values for the determination of group differences. The p values of the separate group comparisons (Conover-Iman comparison) following the significant Kruskal-Wallis test are not included in this table.

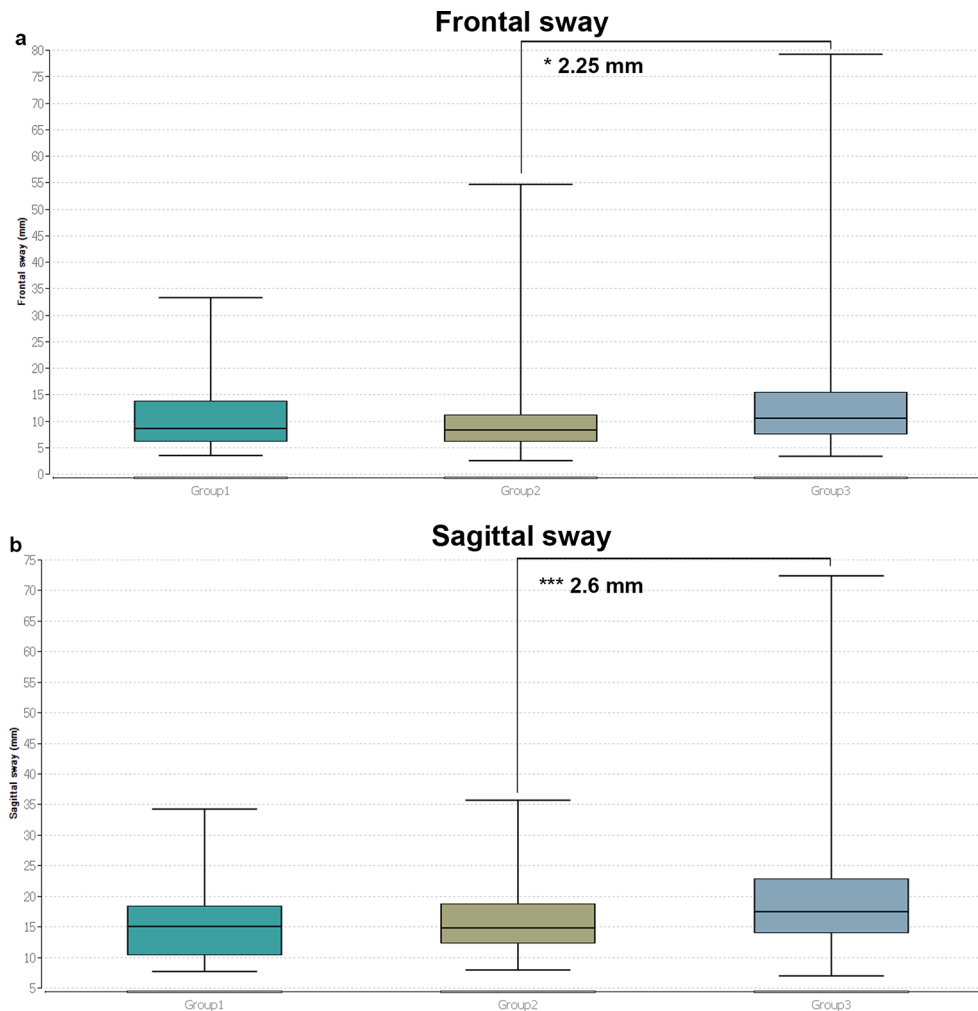


Figure 2 a and b Frontal and sagittal sway due to BMI. BMI, body mass index.

third percentile 13.2 mm. The median of sagittal sway is 16.4 mm (12.6 mm/20.5 mm). The Kruskal-Wallis test finds significant differences for the frontal ($p < 0.04$) and sagittal sway ($p < 0.001$). The Conover-Iman comparison shows a significant difference between group 2 and 3 in regard to the frontal ($p < 0.01$) and sagittal ($p < 0.001$) sway. The median of the frontal sway indicates a smaller median in group 2 (8.2 mm) than in group 3 (10.5 mm). In the sagittal plane, there is a higher sway in group 3 than in group 2 (group 3: 17.4 mm; group 2: 14.8 mm) (table 4a; figure 2a,b). The percentage of load distribution shows no significant differences.

Group comparison due to BMI

Table 4 shows the p values of the group comparison of the working years (postural sway). There are significant differences between the BMI groups as to the frontal ($p < 0.04$) and sagittal ($p < 0.001$) sway (table 4; figure 3a,b). In both parameters, a difference (Conover-Iman comparison; $p \leq 0.01$) between groups 1 and 4 is observed, whereas a difference of the median is present with respect to the frontal fluctuation of 4.2 mm and in the sagittal fluctuation of

7.0 mm (table 4b). No significant differences could be evaluated regarding the parameters of plantar pressure distribution.

Working years group comparison due to BMI

There is a significance of $p \leq 0.03$ due to the comparisons of the BMI of the three working year groups. The following Conover-Iman comparison reveals group differences ($p \leq 0.03$) between groups 1 and 3 and between groups 2 and 3. In the first group, the median is 27.4 kg/m², in the second group 27.7 kg/m² and in the third group 30.0 kg/m² (figure 4). This results in a median increase of BMI by approximately 2.6 kg/m² between the first and the third age group.

Group comparison between subjects with and without back pain

In total, 111 (61.7%) out of 180 participants suffered from back pain. The Mann-Whitney U test plus Bonferroni-Holm correction found no significant differences between both groups (back pain vs no back pain) with respect to all measured parameters.

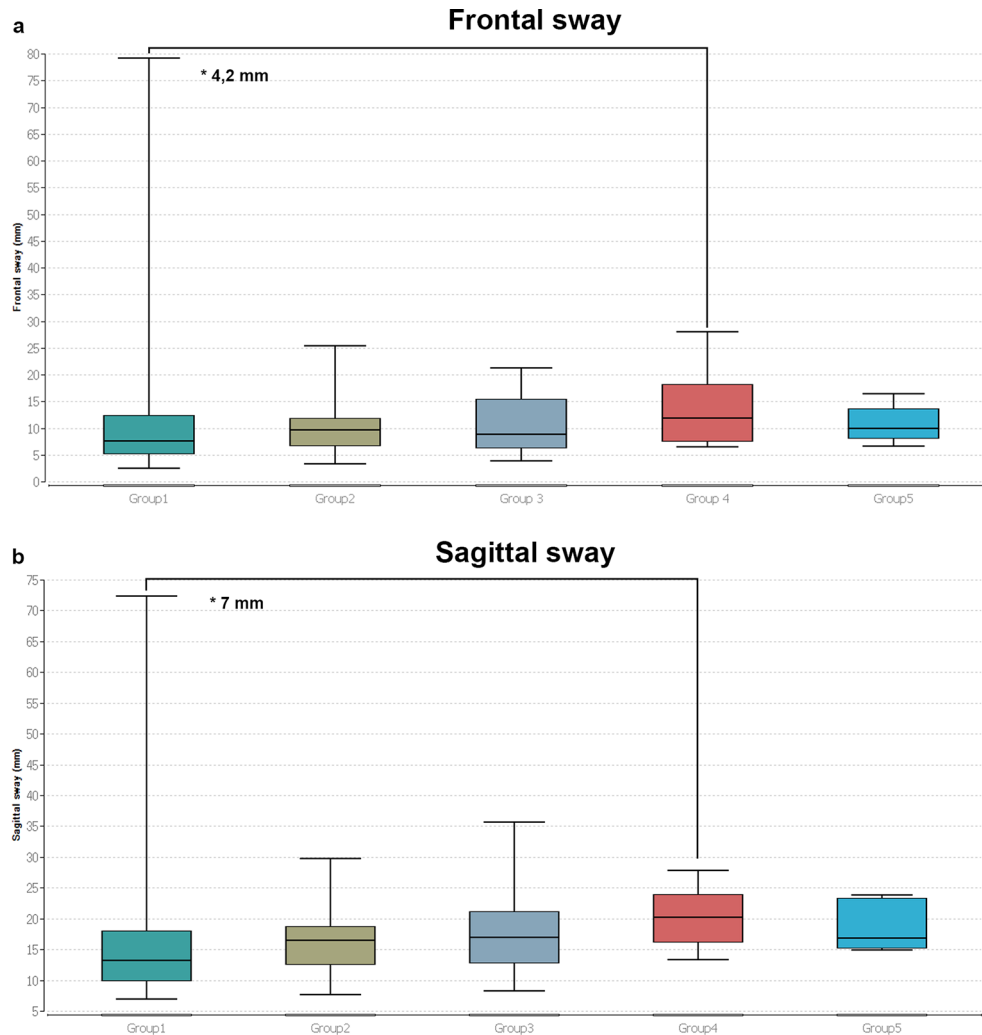


Figure 3a and b Frontal and sagittal sway in comparison of working years.

DISCUSSION

Truck drivers spend most hours of the day in a forced sitting position which probably contributes largely to their tendency to be overweight and to their suffering from back pain. The additional lack of exercise and an

unhealthy diet may cause further damage to their health. Long sitting may impair the muscular-skeletal system resulting in back pain.

The present results confirm impaired postural sway in truck drivers. Since the working conditions cause

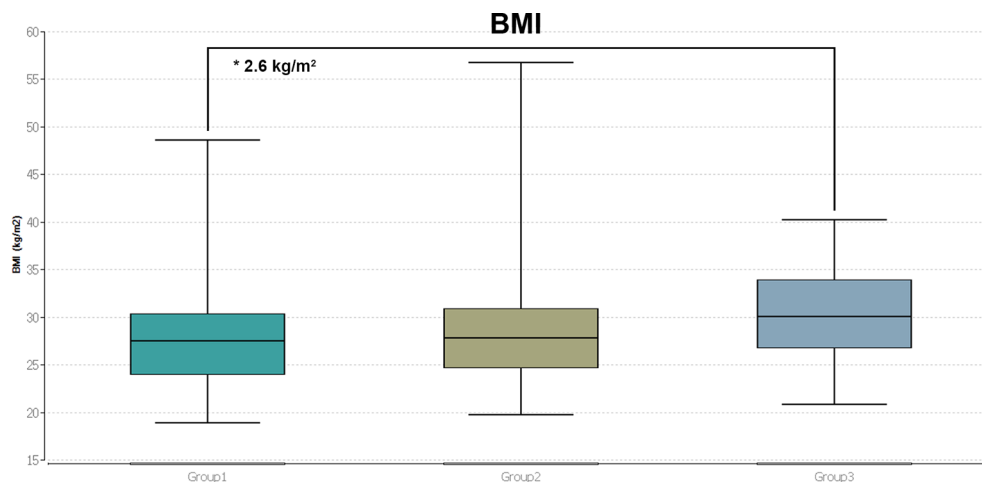


Figure 4 BMI distribution: group 1 (0–12 working years), group 2 (13–25 working years) and group 3 (>26 working years). BMI, body mass index.



continuous damage, we classified truck drivers according to their years of work.

Significant differences are associated in the frontal and sagittal sway with a longer professional life increasing by 22% (2.3 mm) in sagittal and 15% (2.6 mm) frontal in sway from group 2 (13–25 years of work) to group 3 (26 and more years of work) (figure 2a,b).

However, long-term truck driving does not result in a significant, unilateral, pathological redistribution of percentage load distribution of body weight.

The group comparison of BMI groups (WHO classification) shows that the increase of frontal (4.2 mm) and sagittal (7 mm) sway corresponds to the rise of the BMI between normal weight and obesity °2 participants (figure 3a,b). Changes in the percentage weight distribution could not be recorded here.

There is a significant (steadily increasing) link between the number of years worked as a truck driver and an increase in BMI. Truck drivers have been found to be overweight for the most part, which was shown already by other authors.^{11 13 27} Especially the sedentary lifestyle through long sitting hours in the driver's cabin and an unhealthy diet have to be mentioned as explanations for the high prevalence of obesity among truck drivers.^{24 25 28}

In total, less than a quarter of the examined truck drivers could be classified to be of normal weight (23.6%) whereas more than a third of the studied truck drivers suffered from severe obesity (obesity °1–3 (groups 3–5)) (37.2%). In our study, the percentage value of overweight subjects is higher (76.1%) than in other similar studies with 67% (including pre-obesity (group 2)).²⁴

In addition to the number of working years, growing obesity with increasing working time can be seen as a factor influencing the increasing deflections of the frontal and sagittal sway of the COP. Age may be an additional factor which could explain our observations but must be analysed with a larger database.

Birtane and Tuna¹¹ explained a ventral shift of the body's centre of gravity by abdominal fat. Since we have no indicator for the abdominal fat, the relevance of this factor could not be established. We did not find significant changes of the rearfoot–forefoot pressure distribution.

As proven in other studies, truck drivers often suffer from degenerative diseases of the locomotor system and diseases of the muscular-skeletal system.^{20 21} The results of our study correspond to those of other authors,¹⁸ in which long periods of sitting encourage an increase of frontal and sagittal sway. Possible reasons why long-term truck driving does not affect the redistribution of the weight distribution has to be examined in further studies.

Comparing studies between truck drivers and the normal population have already shown²³ that truck drivers more often suffer from back pain. This can be confirmed in our study. Almost 62% of the participating

truck drivers indicate that they are suffering from back pain. Nevertheless, no objective differences between truck drivers with and without back pain could be found.

Consequently, back pain is not a factor influencing the postural sway.¹⁴ Obesity and lack of exercise and sports—two favourable factors for the onset of back pain—are widely common in truck drivers.²⁸ Future studies might examine this coherence more precisely.

Based on the findings, truck drivers might be offered individual health promotion offers. Fitness studios might be included in motorway service stations. Health insurance companies might offer incentives for the use of these fitness rooms. In addition, the driver's seat might be improved and the occurrence of back ache reduced by developing individualised seats, for example, by optimised suspension.

It can therefore be shown that obesity is prevalent among truck drivers. This also has an effect on postural sway, as there is an increase in the frontal and sagittal sway.

Moreover, it seems that working as a truck driver for several years and the long period of continuous upright sitting position disturbs the postural sway mechanisms, which results in an increase of sway. Other studies already stated the influence of obesity and long-term sitting on the postural control.^{10 13}

CONCLUSION

It can only be concluded that the frontal and sagittal sway of truck drivers is associated with long sitting, BMI and age. Significant objective effects of back pain on postural sway could not be proven. Measuring postural sway might serve as an early indicator of musculoskeletal dysfunction^{7 8} which may be improved by physical activity and/or weight reduction. This study supports the findings of other studies which showed a coherence between musculoskeletal dysfunction and postural control.

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Contributors DO, PT, AL, EW, JN and DG made substantial contributions to the conception and design of the manuscript. DO, PT and AL made substantial contributions to the construction of the measurement protocol. DO and PT has been involved in the statistical data analysis. All authors have read and approved the final manuscript.

Competing interests None declared.

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Data sharing statement For additional data see Supplementary Data.

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