Evaluation of the Mechanical Distraction Effect of the HAPO BR by Measuring Changes in Stature

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ABSTRACT

The HAPO BR is a non-motorized physical assistance device (exoskeleton) designed to apply a mechanical distraction action to the spine, with the aim of providing immediate relief associated with this tensioning action. This study aims to objectively assess (1) the immediate mechanical effect of the device by measuring changes in stature and (2) the evolution of this effect throughout the day. Twenty-five adults (17 men and 8 women) participated in the study with the exoskeleton worn but not activated, and then with the exoskeleton activated, in the morning, at midday, and at the end of the afternoon. An increase in stature was observed after activation, with an average value of approximately 4 mm at the end of the day and individual values reaching up to 10 mm. The study thus provides a first objective indication supporting the immediate mechanical effect of the HAPO BR.

Keywords: Passive exoskeleton, spinal distraction, change in stature

1. INTRODUCTION

Human stature varies throughout the day as a result of the mechanical stresses exerted on the spine. This phenomenon is notably associated with variations in the hydration of the intervertebral discs under the effects of gravity and physical activity (e.g., load carrying), and stature may partially recover after a period of rest. Tyrrell, Reilly, and Troup measured an average variation of 19.3 mm in young adults, with a particularly marked loss of stature at the beginning of the active day [1]. Stature measurement therefore provides a simple biomechanical indicator for studying the effects of loading (intradiscal pressure) and recovery mechanisms on the spinal column.

Furthermore, intradiscal pressure measurements performed by Nachemson showed that the load applied to the discs varies depending on body position and the tasks performed [2]. Figure 1 shows that a posture involving trunk flexion while carrying a load is particularly demanding and is associated with high intradiscal pressure in the lumbar region. Conversely, lying supine is associated with lower pressure. These findings provide a general biomechanical framework for understanding the potential value of a mechanical action aimed at temporarily reducing certain compressive stresses. However, they do not allow intradiscal pressure to be directly inferred from a simple measurement of stature.

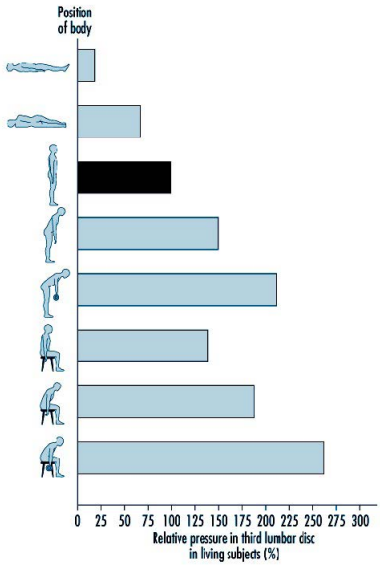

Figure 1 - Relative pressure at the level of the third lumbar disc depending on body position. According to Nachemson

Professional exoskeletons are physical assistance technologies designed to support users in performing their tasks. The work of Theurel and Desbrosses shows that back-

assistance exoskeletons can, in particular, reduce certain levels of muscular exertion during tasks involving trunk flexion or load carrying [3]. More broadly, Theurel *et al*. emphasize the importance of evaluating exoskeletons according to the assistance principle specific to each device and based on objective parameters [4]. While most professional back exoskeletons provide mechanical assistance during trunk flexion, other models, such as the HAPO BR, are designed to generate a mechanical distraction action on the spine when activated.

The present study aims to objectively assess the effect of the HAPO BR by measuring changes in stature. This measurement will be assessed at different times of the day to determine whether the magnitude of the change in stature associated with device activation varies throughout the day, in relation to the changes in stature described by Tyrrell *et al*. [1].

2. EXPERIMENTAL PROTOCOL

a. Participants

Twenty-five healthy adult participants took part in the study after signing an informed consent form. The panel consisted of 8 women (168 ± 4 cm, 72 ± 8 kg, 30 ± 9 years) and 17 men (179 ± 8 cm, 73 ± 13 kg, 31 ± 12 years). All participants were employees of ErgoSanté and were involved either in office-based tasks (excluding the Design Team in order to limit potential bias) or in production tasks.

b. Exoskeleton

The HAPO BR (ErgoSanté, Anduze, France) is a lightweight, non-motorized exoskeleton (0.885 kg) designed to provide immediate back relief. It consists of two textile belts positioned around the hips and floating ribs, and two pairs of fiberglass spring rods. Once activated using two straps located on either side of the exoskeleton, the spring rods separate the two textile belts, thereby generating a distraction action on the spine. A representation of the exoskeleton and its components is provided in Figure 2.

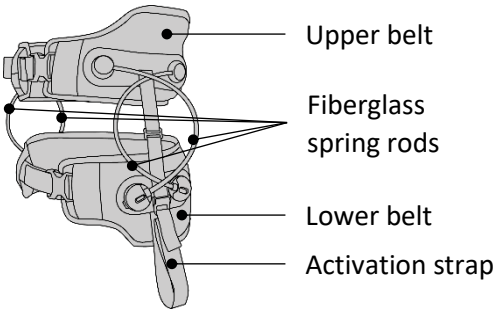

Figure 2 - HAPO BR exoskeleton

c. Procedure

The effect of the HAPO BR was assessed by measuring changes in stature. Each participant, fitted with an exoskeleton adapted to their body morphology, stood barefoot with their heels against the wall, their gaze horizontal, and their arms extended at shoulder height, in order to promote measurement reproducibility. Two conditions were compared:

(A) exoskeleton worn but not activated;
(B) exoskeleton activated.

The height of the top of the head was measured using a stadiometer fixed to the wall. The difference between the two measurements was defined as the ΔS in stature. Each measurement was performed in a randomized order (exoskeleton activated or not) in order to limit any potential bias related to the order in which the conditions were presented.

The procedure was performed at three times during the day: in the morning (H), before noon (H+3 h), and at the end of the day (H+8 h). Outside these measurement periods, each participant was instructed to resume their usual work activities. This organization made it possible to observe whether the measured effect varied according to the time of day and the level of cumulative mechanical loading, as described by Tyrrell *et al*.[1].

(a) (b) (c)

Figure 3 – Experimental protocol: (a) participant posture with the exoskeleton activated or not; (b) exoskeleton deactivated; (c) exoskeleton activated

3. RESULTS

The measurement results presented in Figure 4 show an increase in stature, regardless of the time of day. The difference was more pronounced at the end of the day, with a mean and standard deviation of 4.3 ± 1.1 mm, compared with 3.1 ± 2.1 mm in the morning and 3.8 ± 2.3 mm at midday. The observed effect corresponds to an immediate change in stature measured after activation of the device. However, inter-individual differences should be noted, as some participants exhibited a change in stature (ΔS) of up to 10 mm. This change constitutes an indirect indicator consistent with the exoskeleton's mechanical spinal distraction action, but it should not be considered equivalent to a direct measurement of intervertebral spacing or intradiscal pressure.

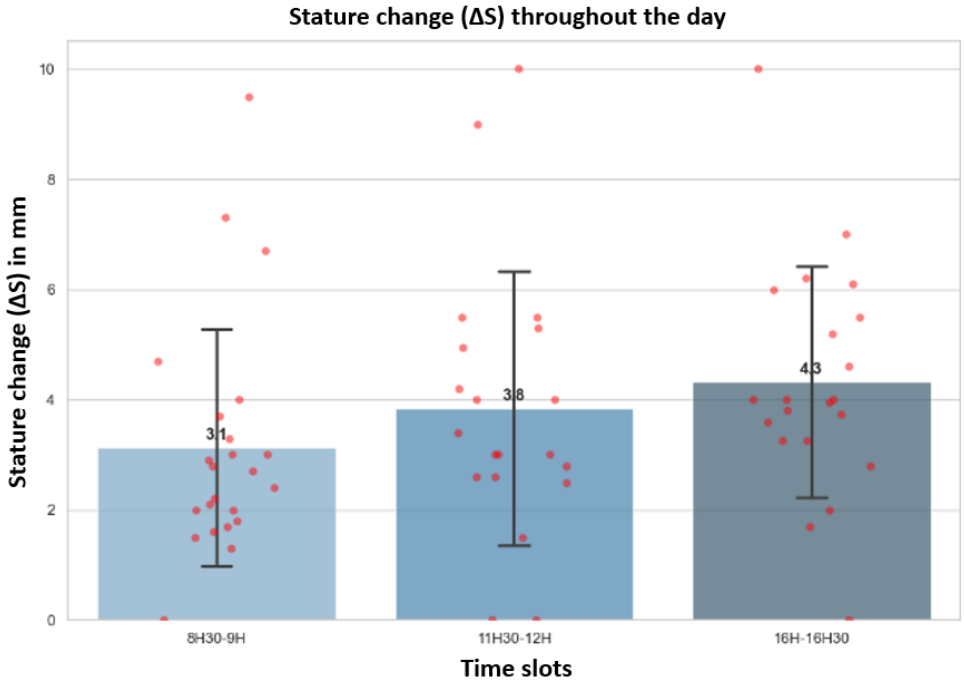

Figure 4 – Stature change(ΔS) throughout the day. The values represent the change in stature measured after activation of the device..

4. DISCUSSION

The results suggest that activation of the HAPO BR produces an immediate mechanical effect detected through stature measurement. The fact that the mean change was greater at the end of the day is consistent with studies showing that stature varies with daily spinal loading, as reported by Tyrrell *et al.* [1]. This observation is also compatible with the mechanical principle of the device: applying a distraction action that may compensate, at least partially and temporarily, for a reduction in stature associated with loading.

Nevertheless, three levels of interpretation should be clearly distinguished. First, the study demonstrates a measurable change in stature. Second, this change is consistent with a mechanical distraction action. Third, it does not allow intradiscal pressure to be measured directly or any potential change in the space between spinal structures to be quantified. The work of Nachemson [2] shows that intradiscal pressure depends on posture and the tasks performed, but it does not allow a ΔS measured using a stadiometer to be directly converted into a change in pressure.

Finally, the literature on back-assistance exoskeletons shows that these devices reduce back muscle exertion (latissimus dorsi and longissimus), both during static trunk-flexion tasks and dynamic load-carrying tasks [3]. These findings reinforce the value of further investigations specifically focused on mechanical spinal distraction principles, as implemented in the HAPO BR exoskeleton.

5. LIMITS

Several limitations of the study should be noted. First, the measurement of stature may have been influenced by the participant's positioning or by a potential spontaneous change in posture between two successive measurements, although participants were instructed to maintain the same posture under both conditions. Repeated measurements and an analysis of intra- and inter-experimenter reliability would help strengthen the robustness of the results.

Second, the protocol focused exclusively on differences in participants' stature and therefore does not allow any conclusions to be drawn regarding changes in intradiscal pressure, intervertebral spacing, or subjective benefit. Additional instrumented measurements would be necessary to improve understanding of the short-, medium-, and long-term impact of wearing the HAPO BR exoskeleton.

Finally, this study was conducted on young, healthy individuals who were employees of the ErgoSanté group, which may constitute a source of measurement bias.

6. PERSPECTIVES

A next step could be to complement stature measurements with more direct biomechanical methods, such as measuring the forces exerted by the device, performing a kinematic analysis of alignment, measuring pressure, or assessing other instrumented parameters where technically and ethically appropriate. It would also be relevant to assess the repeatability of the effect in the same user, its evolution across different postures, and the user's immediate perception upon activation.

7. CONCLUSION

This study demonstrates a measurable increase in stature immediately after activation of the HAPO BR, with a mean change of approximately 4.3 mm at the end of the day and individual values reaching up to 10 mm. This result is consistent with the mechanical distraction principle targeted by the device and provides an objective indicator of its immediate effect on stature.

However, the HAPO BR should be considered here as a professional exoskeleton whose purpose is to create spinal distraction with the aim of providing immediate relief associated with this mechanical action. Stature measurement alone does not allow intradiscal pressure changes to be quantified or long-term conclusions to be drawn. Further investigations are therefore required to more precisely characterize the biomechanical mechanisms, the repeatability of the effect, and the user's immediate perception.

CONFLICTS OF INTEREST

The authors are affiliated with the company that manufactures and distributes the tested exoskeleton.

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