POSTURAL AND MUSCULAR ANALYSIS OF THE IMPACT OF TIBIAL SUPPORT EQUIPMENT ON AN OPERATOR PERFORMING LIFT AND REACH IN FRONT

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I. INTRODUCTION

A study of the *Stand-Rite Pro System*[1] manufactured by Human *Balance and Stability System* was carried out in Nancy in early March 2019. Its purpose is to observe the reductions or increases in constraints concerning an operator's posture. During the analysis, particular attention is paid to the back, hips and knees.

Picture 1: Stand-Rite Pro

II. MEASUREMENT PROCEDURE

The study was conducted on two male persons aged 27 and 29 years. In order to test the impact of the SRP in an environment as close as possible to real operating conditions, a pre-validated measurement protocol described the movements that operators had to perform.

II.1. SENSORS USED

In order to quantify the effect of the SRP on an individual, motion sensors and electromyographic sensors (EMG) were used:

II.1.A. MOTION SENSOR

Postures and movements are collected using "*Motion*" sensors and CAPTIV software, both developed by TEA. *T-Sens Motion* have been used in a full-body set-up (15 sensors).

[1] abbreviated as *SRP* in the document.

Picture 2: T-Sens motion

T-Sens Motion sensors are Inertial Units Measurement (IMU) that merge data from accelerometers, gyroscopes and magnetometers to obtain the orientation of the sensor in space. The combined use of several sensors of this type allows the precise reconstruction of the avatar in three dimensions and the calculation of the joint angles of one or more joints of the human body.

II.1.B. DEFINITION OF THE THRESHOLDS USED

The joint comfort thresholds used in the analysis are provided by:

- « ERGONOMIE », H. MONOD ; B. KAPITANIAK. *Collections des Abrégés de Médecine.* 2009, 2ème édition, 272 pages.
- Norme NF X35-119 Ergonomie - Manipulation à fréquence élevée - Évaluation et valeurs seuils de la contrainte biomécanique de tâches répétitives des membres supérieurs
- ED 957 « Les troubles musculo-squelettiques du membre supérieur (TMS-MS), INRS, 2011

Tables 1, 2 and 3 summarize the different angular thresholds used for this study:

	Back			
Angle (°)	Rotation	Flexion	Extension	Lateral Flexion
Orange zones	-15	30	-10	10
Red zones	-30	45	-20	20

Table 1. Back joint thresholds

	Hip				
Angle (°)	Flexion	Extension	Abduction	Adduction	Rotation
Orange zones	70	-10	20	-10	-10
Red zones	100	-20	30	-20	-20

Table 2. Hip joint thresholds

	Knee		
Angle (°)	Flexion	External rotation	Internal rotation
Orange zones	-15	10	-10
Red zones	-30	20	-20

Table 3. Knee joint thresholds

Note: *An angle reference guide is attached to this report.*

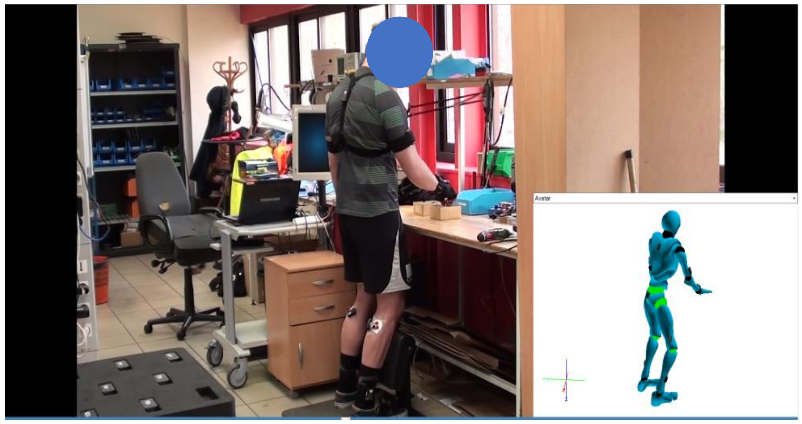
II.1.C. MUSCULAR SENSOR

Eight *T-Sens EMG* were placed on the back (lumbar and dorsal) as well as on the flexor and extensor muscles of the knee (quadriceps and lateral gastrocnemius).

Pictures 3 to 5. Positioning of EMG sensors on the test individual

II.2. STATIC ACTION

The operator performed an action with the arm extended without changing his posture (picture 5). This action was performed over a one-minute period of time.



Picture 6. Static action with extended arm

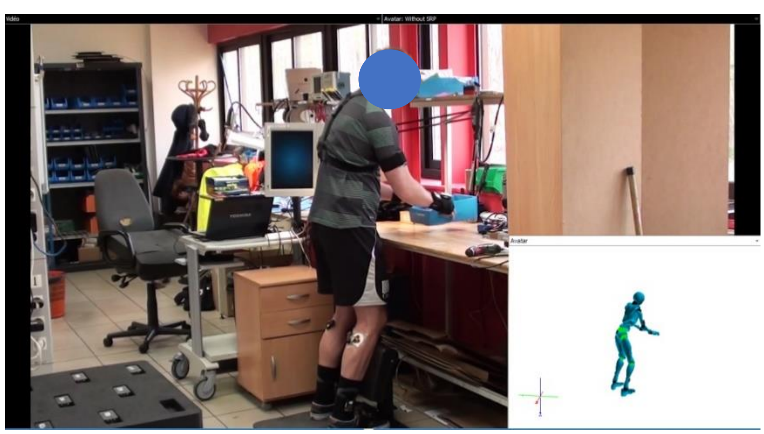
II.3. LOAD DISPLACEMENT ACTION

The individual performed a load displacement action. The load used in this situation is a 1.5 kg (3.3 lbs) box. To ensure the accuracy and repeatability of the individual's movements, five positions have been defined with the use of markers:

- In front of the individual (standard position)
- On a high position
- On the workbench (left side)
- On the workbench (right side)

All displacements were repeated five times in each of the following cases:

- Without SRP
- With a two-legged use of the SRP.



Picture 7. Load displacement action

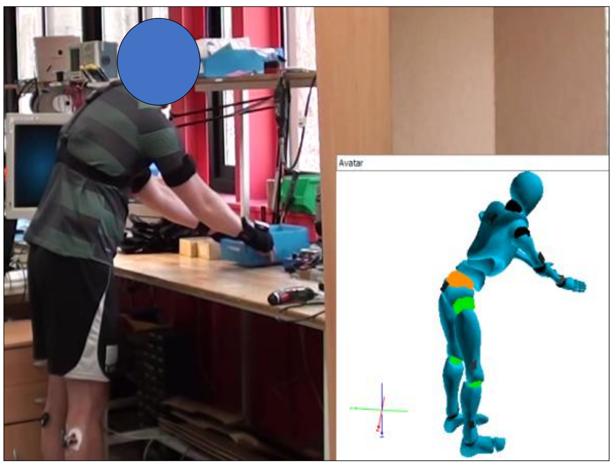
III. RESULTS

III.1. MOTION ANALYSES

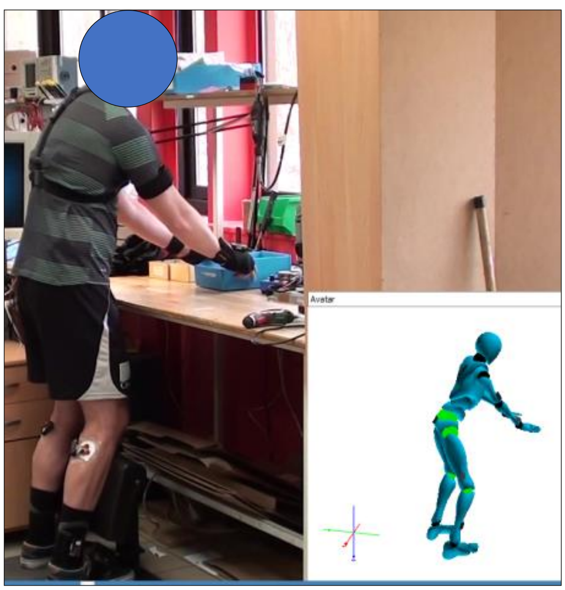
In this preliminary study, out of five actions of the different ones carried out, four of them do not show an increase or decrease in angular stresses. The main activity that shows significant change is "forward load displacement ("lifting front").

Regardless of the action performed and the use or not of the SRP, angular data related to hips and knees constantly remain in the green zones. Therefore, only the back joints data will be presented in the angulation analysis section.

III.1.A. LIFTING FRONT



Picture 8: "Lifting front" activity without SRP



Picture 9: "Lifting front" with the SRP

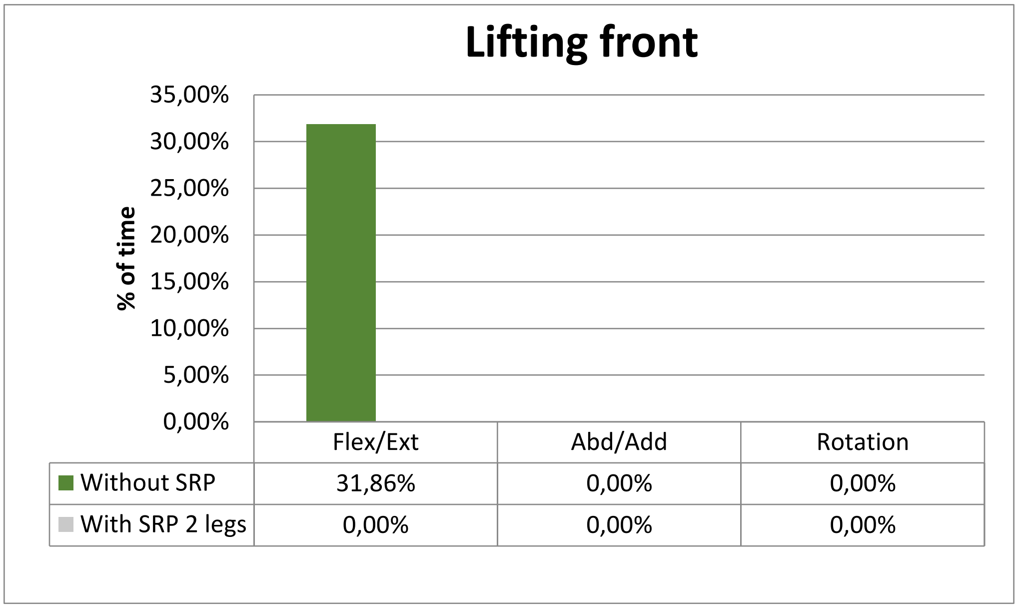


Figure 1. Exposure to back postural risk areas during the "lifting front" activity
(expressed in percentage over the whole activity duration)

A main observation can be made. There is a significant reduction in the frontal bending stress of the back (31.8 %).

With regard to this activity, the **SRP helps to reduce back joint stress.**

III.1.B. CONCLUSION

Through the angulation analyses performed, two conclusions can be drawn about the impact of the use of a SRP on an individual's posture.

1. The SRP allows the operator to keep his back straight when reaching for distant objects on a work surface. The distance at which these objects may be located can be greater while keeping a straight back and thus reducing the associated risks.
2. The SRP can be used as a support and to keep the back straight for minor rotational movements, coupled with frontal and lateral flexions.

III.2. MUSCULAR ANALYSIS

Electromyography sensors (EMGs) were positioned on the following muscles:

- lumbar and dorsal muscles (Erector Spinae),
- quadriceps (rectus femoris),
- calves (lateral gastrocnemius).

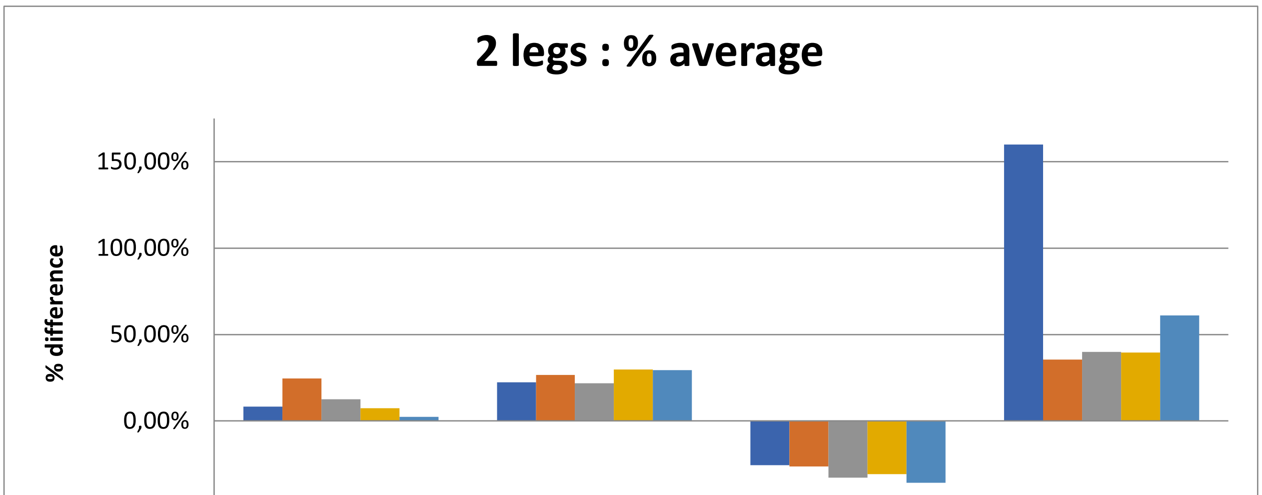
The following results are expressed in percentage (%) and were obtained by dividing the difference in the RMS (Root Mean Square) values of the EMGs signals between the same activities with and without SRP by the RMS value of the EMG signal without using the SRP: a positive value shows a reduction in muscle strain while a negative value shows more intensive muscle use.

$$\text{Values\%} = \frac{RMS(withSRP) - RMS(Withtout\ SRP)}{RMS(Withtout\ SRP)}$$

When the activity is symmetrical (such as in a two-legged use of the SRP) the same results trends appeared for both right and left sensors: an average of the two values was used. On the contrary, for a one-legged use of the SRP, the data were obviously asymmetrical, justifying the need to perform two separated analyses.

Moreover, values that range between -10% and +10% are not significant enough to indicate a decrease or increase in constraints, as they can originate from a variation in the gesture added to other factors.

III.2.A. TWO-LEGGED USE OF THE SRP



	Back	Lombar	Quadriceps	Gastrocnemius
Static	8,17%	22,38%	-25,61%	159,84%
Lifting front	24,55%	26,54%	-26,30%	35,51%
Top	12,55%	21,70%	-32,79%	39,83%
Right	7,30%	29,72%	-30,88%	39,46%
Left	2,25%	29,41%	-35,90%	60,98%

Figure 2. Comparison of the muscular efforts between a two-legged use of the SRP and an absence of SRP

We can notice that the use of the SRP:

- reduces constraints on the lumbar and calf muscles on the various activities performed;
- reduces back muscles constraints for the *lifting front* and *lifting top* activities but does not provide significant support for other activities;
- requires additional strength from the quadriceps muscles.

III.2.B. CONCLUSION

To sum up the EMGs results, we find that the use of the SRP with two legs reduces stress on the extensor muscles of the back and the flexor muscles of the knee. However, it also can shift these constraints to the extensor and rotator muscles of the knee.

III. DISCUSSION AND CONCLUSION

The use of the Stand-Rite Pro system leads to a change in the movement strategy of individuals: some will use it with one, other with two legs while they could stay on it for the whole duration of a task or, on the contrary, just help themselves at the end of a particular gesture.

To be able to compare similar actions with and without the SRP, it was therefore necessary for us to *force* the operators' postures by clearly defining them. This protocol to highlight situations where the SRP led to clear improvements.

The Stand-Rite Pro seems to be extremely beneficial in one particular case, namely when an operator has to perform a *load lifting at arm's length*. In that case, we observe:

- a significant reduction in postural stress in back flexion (31.8 %)
- an overall reduction of muscular constraints:
  - constraints reduction of more than 24 % for the back muscles
  - constraints reduction of more than 26 % for the lumbar muscles
  - constraints reduction of more than 35 % for the calf muscles
  - requirement for additional quadriceps muscle strengthening (27%).

The overall observation is that a good use of the SRP leads to a reduction of postural and muscular constraints of the back, even if these constraints (especially muscular ones) are shifted to the lower limbs (e.g. knee and hip). In all, the Stand-Rite Pro is efficient when it comes to lift a load at arm's length.