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EFFECTS OF THE COMBINATION POSTURES OF TRUNK, SHOULDER AND LEG ON PERCEIVED EXERTION IN MANUAL HANDLING TOOLS

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ABSTRACT

An expanding body of literature recognises the importance of assessing coordinated postures to overcome the possibility of under/over-assessing in the available posture's assessment checklists. In addition, the interaction between the upper and lower limbs has yet to be considered. Therefore, this study investigates the impact of the main and combination of shoulder, trunk and leg support postures in a horizontal drilling task on the rating of perceived exertion (RPE). A total of 10 male participants with a mean age of 23.3 ±0.7 were selected for the experiment. The general linear model (ANOVA) was used to analyse the data. Results show that shoulder flexion, trunk bending forward and leg support have significant effects on RPE ($P < 0.01$). Moreover, leg support reduces the discomfort for all postures with an approximate value of 1 on the Borg's scale. The difference in RPE at a shoulder flexion angle of 45°– 90° was likewise determined to be twice of 0°–45° for all coordinated postures. These findings can be beneficial in designing tasks based on trunk, shoulder and leg support to decrease musculoskeletal disorders, save energy, and increase efficiency.

Keywords
Musculoskeletal disorders (MSDS).
Shoulder.
Trunk.
Leg support.
Perceived exertion.

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1 INTRODUCTION

Musculoskeletal disorders (MSDS), such as low back and upper limb pain (LBP and ULP, respectively), are the most common work-related injuries in handling tools manually. Assembly companies in the US expend billions of dollars on limited productivity caused by work-related MSDS of employees. This situation has been proven financially by the demands for worker compensation, lawsuits, insurance bills and disability, as well as the process of contracting and preparation of a new workforce [1].

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Numerous studies on the work environment have shown that awkward body posture can cause varying degrees of discomfort and stress in the workers' musculoskeletal system. Karhu et al. [2] developed the Ovako Working Posture Analysis System (OWAS), which is a practical method to identify and evaluate poor working postures. The advantage of OWAS is that it can be implemented through observation. However, although this method is easy to understand, OWAS is challenging to apply to different work positions with repetitive activities that the body cannot precisely distinguish. McAtamney and Corlett [3] developed the Rapid Upper Limb Assessment, which simply evaluates the upper limb as used in different industrial workplace settings but does not assess the lower limb. Hignett and McAtamney [4] proposed the Rapid Entire Body Assessment that notes the details of the initial phase in the improvement of a postural analysis tool, which includes static and dynamic load factors.

A relatively limited body of literature represents the possibility of under/over assessing body postures through the combination of the upper limbs. Na et al. [5] determined that the main and coordinated postures of the shoulder flexion/extension and elbow flexion with different external loads are statistically significant on the perception of comfort. Khan et al. [6] concluded that the effects of elbow flexion on the forward flexion of the upper arm and shoulder are positively related to both body parts in terms of the maximum voluntary contraction (MVC) of grip strength. Brookham, Wong et al. [7] used electromyography to determine that a 60° shoulder flexion and −45° internal rotation form part of an excellent posture whilst handling light tool tasks. Lee [8] reported that the postures of the shoulder/elbow (0/90° and 90°/180°) exhibit the most ideal worker holding capability. Farooq and Khan [8] investigated the combination of shoulder/elbow posture for a repetitive gripping task and learned that the 45° elbow flexion angle with −45° shoulder extension exhibits the most awkward posture.

Trunk flexion has a significant impact on heart rate, subjective perception and muscle activity [9, 10, 11]. Kong et al. [12] assessed the combination of the trunk, shoulder, and elbow flexion angles to hold a 0.5 kg load in a sustained manner. The results showed that the discomfort, MVC percentage and heart rate are substantially low when the shoulder flexion is 45°. Damecour et al. [11] determined that supporting the trunk at the height of the sternum significantly decreases muscle activity.

All previous studies did not consider the combination posture of shoulder flexion and trunk bending forward with leg support and have not conducted real tasks, such as drilling with the most predictable posture range of the trunk, shoulder and leg. In addition, Khan and Muzammil [13] exposed that the drilling task is inherently boring and repetitive, with many health and safety concerns such as repetitive stress injury and MSD. Yu et al. [14] found that most furniture excavation tasks in China are in semi-automatic case that workers still need to do a lot of manual work. Therefore, they are prone to inefficiency and fatigue. Hambali et al. [15] studied the work posture in the mechanical assembly division of ABC Sdn. Bhd. in Malaysia. The results showed that the highest comfortable risks occurred in the drilling section. Shokshk et al. [16] determined the effects of trunk bending forward, shoulder flexion and anthropometry on heart rate in horizontal drilling task. The results showed that the heart rate increased with the rise of trunk bending forward and shoulder flexion. Shokshk [17] studied the energy consumed of shoulder flexion and trunk bending forward in horizontal drilling task. The results showed that the energy expended increases with increasing shoulder flexion and trunk bending forward away from the neutral position. Therefore, the goals of the present study are to:

1. Investigate the separate and combined effects of the flexion of the shoulder, trunk forward bending and leg support and compares with the rating of perceived exertion (RPE).
2. Explore how the leg's support of the entire body improves the perception of comfort for all predictable postures during a horizontal drilling task.

2 MATERIALS AND METHODS

2.1 SUBJECTS

A total of 10 volunteers who do not have a history of back and shoulder problems were selected for the current experiment. All volunteers have been instructed to use the requisite tools for this experiment. The average age and weight of the participants were 23.3 ±0.7 and 67.3 ±6.4, respectively.

2.2 Apparatus

The category-ratio (CR-10) rating (Borg scale) as shown in table 1 [18], which ranges from 0 (nothing at all) to 10 (extremely strong), was used to assess the RPE of the participants when completing each sub-task.

Table 1. Borg scale CR-10

Scale	Description
0	Nothing at all
0.5	Very, very light
1	Very light
2	Fairly light
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very hard
8	
9	
10	Maximal exertion

2.3 Variable Identification

The three independent variables (IDVs) are the trunk bending angles (0° and 20°), shoulder flexion angles (0°, 45° and 90°) and leg support (NS = no support, WS = with support). Figure 1 shows the 12 interaction postures, namely, S0T0NS, S0T0WS, S0T20NS, S0T20WS, S45T0NS, S45T0WS, S45T20NS, S45T20WS, S90T0NS, S90T0WS, S90T20NS and S90T20WS. The dependent variable is the rating of perceived exertion (RPE). The fixed variables are the diameter of the holes (8 mm), material where the holes will be drilled (polywood) and environmental condition (room temperature with normal humidity).

2.4 Task description

The subjects were directed to execute the first posture as shown in Figure 1 and to drill a series of holes (30 × 8 mm; as one sub-task) on the solid vertical plywood. For the same sub-task between the holes, the subject returns his hand in a repetitive cycle time of two seconds as shown in Figure 2 until all holes have been drilled. To enable the heart rate return to the rest level, the subjects will have a 5-min rest before proceeding to the next sub-task with a different posture. Thereafter, the subjects will be directed toward the next subtask with another posture but performing the previous processes and steps. The process will continue until all 12 sub-tasks are completed.

Figure 1. The coordinated postures of shoulder, trunk and leg

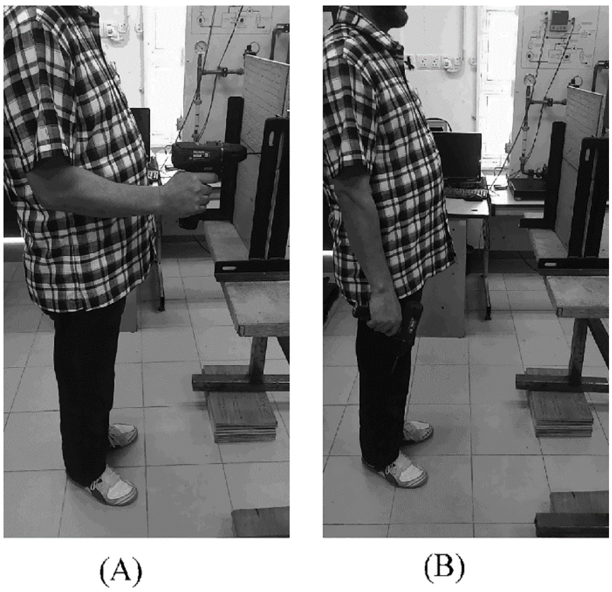

Figure 2. Repetitive cycle movement during each sub-task

2.5 Data analysis

Repeated measures ANOVA also known as interior design in SPSS software was used to analyse the RPE data. This technique compares one or more variables based on repeated observations of multiple time points or different conditions [19]. Significant savings in sample size and high power can be achieved by using repeated measures ANOVA. If the sample size is less than 30, the normal distribution of the base population for each condition or time is required. If the sample size is more than 30, the normal distribution can be ignored [19, 20].

3 RESULTS AND DISCUSSION

3.1 Results

The mean and standard deviation of RPE are summarized in Table 2, which have been obtained from the participants after they completed each sub-task of 12 different combinations of postures of the shoulder, trunk and leg support. Table 2 also shows that the lowest stress perception was at the neutral posture with leg support (RPE = 2.2). The highest stress was during drilling with shoulder flexion of 90° and trunk flexion of 20° without leg support (RPE = 6.9).

As shown in Figure 3 and 4, noticed a clear trend of increasing stress perception with the increase of the shoulder and trunk flexion. Also, Leg support reduces stress with an approximate value of 1 in Borg's scale for each posture. The most interesting aspect of this graph and based on the significant values in adjustment for multiple comparisons (Bonferroni/within-subjects ANOVA) is that the difference in RPE between the shoulder flexion angles of 0° and 45° is 1. By contrast, the difference is 2 between 45° and 90° for all postures.

Table 2. Rating of perceived exertion (RPE) mean and standard deviation (STD.) of all factors

Posture	Shoulder flexion	Trunk flexion	Leg	RPE	STD.
S0T0NS	0°	0°	NS	3	0.89
S0T20NS	0°	20°	NS	4	1.18
S45T0NS	45°	0°	NS	3.9	1.81
S45T20NS	45°	20°	NS	5	1.67
S90T0NS	90°	0°	NS	6	2.57
S90T20NS	90°	20°	NS	6.9	2.17
S0T0WS	0°	0°	WS	2.2	0.87
S0T20WS	0°	20°	WS	3	1
S45T0WS	45°	0°	WS	3	1.79

S45T20WS	45°	20°	WS	4.1	1.45
S90T0WS	90°	0°	WS	5.3	2.65
S90T20WS	90°	20°	WS	6.1	2.02

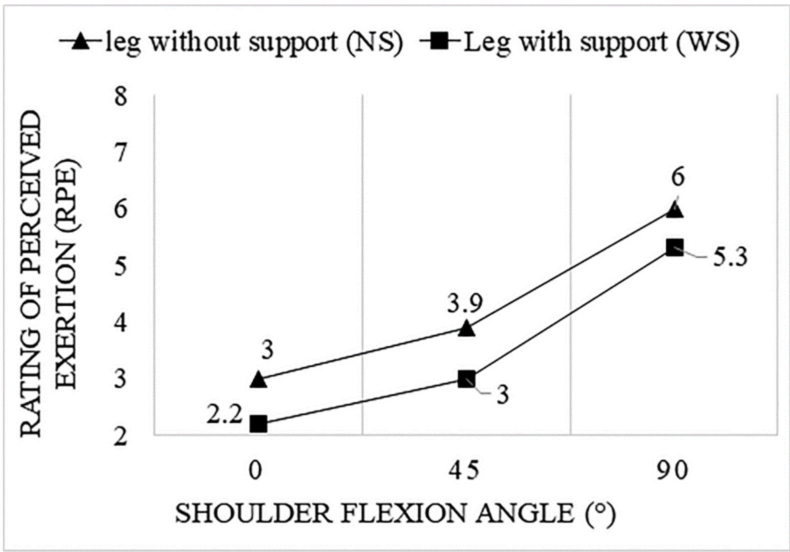

Figure 3. The effects of shoulder flexion and leg support on RPE at trunk flexion 0°

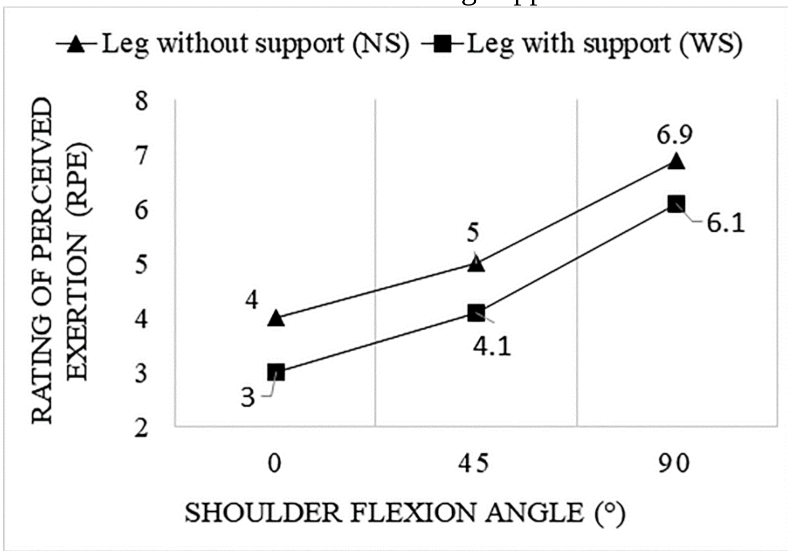

Figure 4. The effects of shoulder flexion and leg support on RPE at trunk flexion 20°

The P value in the Shapiro–Wilk tests of the Standardised Residuals in the repeated measures of analysis of variance (ANOVA) was > 0.05, thereby distribution RPE representing a normal. The factors of shoulder, trunk and leg support postures assumed sphericity, except for shoulder, trunk and leg interaction, where the Greenhouse–Geisser correction was implemented. The within-subjects effects on RPE of the main and interaction factors are shown in

Table 3. Shoulder, trunk and leg support were statistically significant (P = 0.00, 0.04 and 0.02, respectively), whereas the interaction between these factors was not statistically significant.

Table 3. Within-subjects effects ANOVA (RPE)

	Shoulder	**Trunk**	**Leg**	**shoulder * trunk**	**shoulder * leg**	**trunk * leg**	**shoulder * trunk * leg**
DF(Error)	18	9	9	18	18	9	9.919
F	14.003	14.613	20.025	0.136	0.288	0.669	0.144
Sig.	0.00	0.004	0.002	0.874	0.753	0.434	0.736

3.2 Discussion

This study aims to assess the coordinated postures of the shoulder, trunk and leg support on RPE of the subjects during a horizontal drilling task. The results indicate that RPE increases with the increase of shoulder and trunk flexion. However, the perception slop of the shoulder flexion angles of 45° to 90° is higher than that of 0° to 45°. Therefore, the perception ranking of the shoulder flexion cannot be assessed as equal portions from 0° to 90°. This finding is in conflict with previous studies that have ranked the angles of the shoulder flexion based on equal portions [3, 4]. This outcome is also contrary to that of Brookham et al. [7], who determined that −45° internal rotation and 60° shoulder flexion comprise an ideal posture. These outcomes seem consistent with a study of Sasikumar et al. [21] , which determined that shoulder flexion at the chest level has the highest stress based on muscle activity. In addition, Lee [8] determined that the posture of the shoulder/elbow at 0°/90° has the most significant human holding capability.

The estimated marginal means in the within-subject effect of ANOVA revealed that the RPE variance between the trunk flexion angles 0° and 20° was high, thereby indicating the difficulty of accomplishing tasks when bending the trunk. However, the trunk flexion angle should be in a neutral position in vertical tasks whilst handling tools. This result agrees with those of Chung et al. [9], Saha et al. [10], Damecour et al. [11] and Shokshk et al. [16], who determined that trunk flexion has a significant impact on heart rate, subjective perception and muscle activity. This result is also consistent with that of De et al. [22], who determined that the highest grip strength was in a standing posture in a neutral trunk posture. This finding is contrary to those of previous studies, which suggested that the range 0°–20° trunk angle bending forward is acceptable [23]. Such result also contrasts with that of Kong et al. [12], who learned that the discomfort and heart rates for the back flexion angle of 45° with the shoulder flexion of 45° were considerably low.

Supporting the trunk by placing one of the legs one step in front of the other in handling tasks decreases RPE for all postures. The most apparent finding that emerged from the analysis is that leg support is essential to decrease the stress caused by using awkward postures. In terms of job performance, leg support reduces the quickness of work that results from the awkward postures of the trunk and shoulders. This result agrees with that of Damecour et al. [11], who determined that supporting the flexion of the trunk at the height of the sternum decreases muscle activity.

Discussion should explore the significance of the results of the work, don't repeat them. Avoid extensive citations and discussion of published literature. Alternatively, results and discussion may be combined. A combined Results and Discussion section is often appropriate.

4 CONCLUSIONS

The present study was designed to determine the interaction and main effects of the trunk bending forward, shoulder flexion and leg support postures on a subjective perception using the Borg's scale assessment on manual handling tasks, such as drilling and assembly work. Accordingly, this study determined that RPE increases with the increase of shoulder and trunk flexion. Leg support reduces RPE for all postures as well. Therefore, the evidence from this study indicates that the proper posture to handle a tool in low and moderate vertical works, such as drilling, is that trunk bending forward angle should be in the range of 0°–5° and shoulder flexion is in the range of 0°–45° with leg support. The work should involve short sub-tasks of 3 to 5 min with repeated cycles of 2 sec between approximately 10 sec working time. The resting time between sub-tasks should be approximately 4–5 min. The major limitation of this study is the number of main and interactions postures, which can be assessed on the participant. A further study could assess the long-term effects of low, moderate and high posture stress on job performance and MSDs.

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تأثيرات تجميع الوضعيات المختلطة للجذع والكتف والساق على الجهد الملحوظ في أدوات المناولة اليدوية

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الملخص

اهتمت الدراسات الحديثة بأهمية تقييم المواقف المتداخلة (الخلط في وضعية اطراف الجسم المختلفة كالجذع والكتف اثناء العمل) للتغلب على احتمالية التقليل اوالإفراط في تقييم الموضع في قوائم المراجعة المتاحة. لذلك ، تبحث هذه الدراسة في تأثير الوضع الرئيسي والجمع بين أوضاع الكتف، الجذع والرجل في مهمة حفر افقية على الجهد الملحوظ بمقياس بورغ. عشرة (10) مشاركين بمتوسط عمر 23.3 ±0.7 تم اختيارهم لاداء هذه المهمة. تم استخدام النموذج الخطي العام انوفا لتحليل البيانات. تظهر النتائج أن انحناء الكتف ، ثني الجذع للأمام ودعم الساق لها تأثيرات كبيرة على الجهد الملحوظ. علاوة على ذلك ، يقلل دعم الساق من الجهد لجميع المواقف بقيمة تقريبية 1 على مقياس بورغ. لوحظ ايظا ان الجهد الملحوظ بين الزاوية انثناء الكتف 45° و 90° كان 2 بمقياس بورغ والذي كان ضعف الجهد بين الزاوية 0° و45° لانثناء الكتف. يمكن أن تكون هذه النتائج مفيدة في تصميم المهام بناءً على وضع الجذع والكتف والساق لتقليل الاضطرابات العضلية الهيكلية وتوفير الطاقة وزيادة الكفاءة.

الكلمات الدالة:
الاضطرابات العضلية الهيكلية (MSDS).
الكتف.
الجذع.
ساق داعمة.
الجهد المبذول.

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