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Physical Effects of New Devices for Bricklayers

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Bricklaying is a physically demanding job. Bricklayers frequently flex their trunk to pick up bricks and mortar and position these in a wall. The experienced workload is highest working with bricks at 0 to 50 cm from the floor. In this study the effects of 2 devices that have proven to be feasible in practice are evaluated.

The 50 cm raise due to the 2 devices is experienced as comfortable, the estimated lumbar compression force was reduced, and observations indicate likewise. It is discussed that the field experiments have many drawbacks. Nevertheless, based on this study in combination with other literature the improvements could be recommended.

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bricklaying ergonomic innovations construction work
musculoskeletal problems

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1. INTRODUCTION

In The Netherlands approximately 20,000 bricklayers are involved in building new houses, offices and industrial structures, and in renovating older buildings. Their main task is to lay bricks with the use of mortar and towel and the work is done with care to ensure all joints are a uniform thickness and each row is straight. In the Netherlands 90% of the time, 800 bricks of the waal type (weight 17 N) are laid per day (Vink, Munnik, & Voorde, 1996). Other tasks like setting out material, transportation, and communication consume the other 10% of the time. The bricks are set out at ground level behind the bricklayer and therefore the bricklayer bends and rotates his back about 800 times a day (see Figure 1).

Figure 1. Situation of traditional bricklaying.

Bricklayers belong to the top four trades in the construction industry as far as lumbar injuries are concerned (Arbouw, 1994). The financial and social consequences of sick leave and work disability are large. In 1993 the time lost due to sick leave was 13.3% and the number of new disabilities in one year was 4% of the total number of bricklayers (Arbouw, 1994). Fifty-five percent of this sick leave was due to musculoskeletal problems (Arbouw, 1994). The major problem experienced by bricklayers was working between 0 and 50 cm above the floor (Vink et al., 1996).

Also, working methods had not changed for more than 100 years. So, there was certainly room for efficiency improvement. Therefore, the Dutch bricklaying industry alliance (KNB), the Dutch bricklayers' employers alliance (NMPB), the employers' alliance in the Dutch construction industry (NVOB), and the second largest applied scientific research institute in Europe (TNO) developed a new method of bricklaying.

A previous study (Vink & Koningsveld, 1990) showed the positive effects on the musculoskeletal load of raising the height of the bricks in a laboratory. The work was not experienced as more difficult. The back torsion was reduced as well as the back flexion by heightening the bricks. The reduced back flexion resulted in a decrease in compression force on L4/L5 from 1.9 kN (not raised) to 1.5 kN (raised bricks). Comparable data were reported by Jäger, Luttman, and Laurig (1991). Vink and Koningsveld (1990) also showed a reduction in experienced loading and a significant reduction in cardiorespiratory load. However, companies in the construction industry are not convinced about the reduction in back load by using two assistive devices in practice. This study is focused on the back load, because previous studies (Arbouw, 1994; Vink & Koningsveld, 1990) showed that the main complaints of bricklayers are found in the lumbar back. In this study the effects on musculoskeletal loading of assistive devices that appeared to be feasible in practice are studied. The hypothesis is that the devices have no effect on physical load.

Assistive Devices

From 1990 several products to raise bricks and mortar had been developed to reduce trunk flexion. Before implementing innovations it is essential to have support from the participants and to test the innovations. Therefore, together with the sector organizations different products were developed and tested. User tests showed that several products were not feasible. An aluminium height adjustable foldable table was developed and tested by bricklayers. It appeared that the control mechanisms in these tables were too fragile. Dysfunction was due to mortar on the control mechanism or due to damage caused during transport. Other iron tables were too heavy to transport between scaffoldings on different building sites. Foam boxes used to raise the bricks were lightweight, but appeared to be unstable in field tests. In the field tests user-friendliness, safety, implementation possibilities, and comfort ergonomics were evaluated. After several tests and brainstorm sessions two devices were evaluated as feasible and the effects of these devices on lumbar loading were investigated in this project. The two improvements were

- Split floor in scaffoldings
  Traditional scaffoldings were adjusted to enable raising bricks or lowering the bricklayer. By making extra mounting possibilities to the pipes of the scaffolding, boards could be positioned at various heights by the scaffolders. This offers possibilities for lowering the level of the boards for the bricklayer 50 cm or raising the level of the boards where the bricks and mortar are positioned (see Figure 2). The scaffolding made by HC (The Netherlands) can be set up by a crane. On this HC scaffolding the floor is lowered, which reduces forward bending of the bricklayer and reduces the load of the scaffolder, because part of the manual work is eliminated.
- Shores
  A few bricklayer companies used very simple shores of wood or aluminium that could be placed on the scaffolding. These resulted also in a 50 cm raise of the bricks and mortar. The total weight of these shores was 100–200 N depending on the materials used. For the heavier shores the boards and supports could be split to simplify transport.

Figure 2. Bricklaying with a split floor scaffolding with bricks and mortar 50 cm raised.

2. METHODS

Measurements of effects in a naturalistic setting is difficult. However, a laboratory study also does not give certainty on the effects in the field, especially in the construction industry. Every building is different, every building site is different, and several factors like body space influence postures. Valid and reliable measurements are in fact impossible. It was also impossible to find enough situations in practice to study both devices separately. From the first impression the working methods did not differ much. Also, most effects were assumed to be caused by the raising of set out bricks and mortar. Therefore in this study a combination of three indicative experiments is used to find differences between working traditionally and working with the bricks 50 cm raised:

1. Questionnaire on experienced loading;
2. Estimation of L5/S1 maximum loading;
3. Observation of the specific bricklaying task.

2.1. Questionnaire on Experienced Loading

To have an indication of the perceived loading, a group working for a longer period with the raised bricks was needed as short-term effects like getting accustomed should be excluded. However, also experience with the traditional way of working is essential and should be fresh in mind. Therefore, among all bricklayers a group was defined that worked more than 2 years traditionally and in the last year for approximately 50% of the time with the raised bricks. By interviews in the sector one bricklayers' company was found that met these requirements. All 25 bricklayers of this company were asked to complete a questionnaire on experienced loading with the two systems. Questions like whether they prefer traditional working or working 50 cm raised, influence on work pace, and experienced body discomfort after a day working in the different body regions were asked. Differences were tested with the *t* test for paired comparison ($P < .05$).

2.2. Estimation of L5/S1 Peak Loading

To have an indication of the L5/S1 peak loading in the traditional and 50 cm raised way of working, the posture was estimated and the force on the L5/S1 segment was calculated. From previous studies it is shown that most of the time (35–90%) is consumed by bricklaying (Miedema & Vink, 1997), 90% of this time the waal brick is used. To make comparison possible an average task with waal bricks was recorded in the traditional and 50 cm raised situation. Three bricklayers could be found that worked one day in the traditional and one day with the 50 cm raised bricks in comparable tasks.

These bricklayers were videotaped during the two days. For each participant and each condition the seven images were selected from the videotapes where the torso flexion was highest. The average angle of each body segment was calculated from these selected images and tested with the *t* test for paired samples ($p < .05$) and put into the 2dsspp (Chaffin & Andersson, 1991) to calculate the L5/S1 load.

2.3. Observation of the Task

Based on existing studies and interviews with specialists in bricklaying, the average work was defined: working with the waal brick, some windows, some corners, working with teams of three bricklayers and one assistant, and so forth. Then building sites were defined where this “average” bricklaying work could be found. Of both the old and the new situation 10 participants were observed and videotaped during one-day work and additional measurements were made on weights of the bricks and distances. Time consumption of several tasks and frequency of handling were measured with a stopwatch. From the videotape the angle of some body segments relative to the vertical was estimated (trunk, upper arm, lower arm, and head). Also, the horizontal distance between ankle and hand was estimated, the vertical distance between ground and hand and the asymmetry in trunk posture were estimated. These data were analysed and evaluated with the guidelines on physical workload for the construction industry (see Table 1). For lifting knowledge from the NIOSH (National Institute for Occupational Safety and Health) equation (Waters, Putz-Anderson, Garg, & Fine, 1993) was used, for pushing, pulling and carrying the Mital guidelines (Mital, Nicholson, & Ayoub, 1993), and for posture and repetitive work standards No. ISO CD 11226:1995 (International Organization for Standardization, 1995), NF X 35-106:1985 (Association Française de Normalisation, 1985), and prEN 1005-4:1996 (European Committee for Standardization, 1996). These guidelines are based on international available guidelines and on consensus among Dutch ergonomics and the construction industry (Molen & Delleman, 1997).

TABLE 1. Summary of the Guidelines Used to Evaluate the Workload

Activity	Source	Criterion	Evaluation Green	Yellow	Red
		Whole body judgement			
Lifting	NIOSH*	Various	< MPL	MPL – 3 × MPL	> 3 × MPL
one-handed lifting	Mital**	maximal force	> P90 male	P25–P90 male	< P25 male
pushing/pulling	Mital**	maximal force	> P90 male	P25–P90 male	< P25 male
carrying	Mital**	maximal force	> P90 male	P25–P90 male	< P25 male
		Posture (static as well as repetitive movements of more than 2 per minute)			
Upper arm	ISO/CEN***	> 60° elevation	< 1 hr	1–4 hrs	> 4 hrs
Low back 1	ISO/CEN***	> 60° flexion	< 1 hr	1–4 hrs	> 4 hrs
Low back 2	ISO/CEN***	> 0° rotation	< 1 hr	1–4 hrs	> 4 hrs
Low back 3	ISO/CEN***	overextension	< 1 hr	1–4 hrs	> 4 hrs
Neck 1	ISO/CEN***	> 25° flexion	< 1 hr	1–4 hrs	> 4 hrs
Neck 2	ISO/CEN***	> 0° rotation	< 1 hr	1–4 hrs	> 4 hrs
Other joints	ISO/CEN***	extreme angles	< 1 hr	1–4 hrs	> 4 hrs
		Repetitive handlings with hands			
> 2/min	NF X****	force > 85 N	< 1 hr	1–4 hrs	> 4 hrs
> 3/min	NF X****	force > 60 N	< 1 hr	1–4 hrs	> 4 hrs
> 4/min	NF X****	force > 35 N	< 1 hr	1–4 hrs	> 4 hrs
> 5/min	NF X****	force > 20 N	< 1 hr	1–4 hrs	> 4 hrs

Notes. *—NIOSH (National Institute for Occupational Safety and Health) equation described in Waters, Putz-Anderson, Garg, and Fine (1993); **—Mital, Nicholson, and Ayoub (1993); ***—Standards No. ISO CD 11226:1995 (International Organization for Standardization, 1995) and prEN 1005-4:1996 (European Committee for Standardization, 1996); ****—Standard No. NF X 35-106:1985 (Association Française de Normalisation, 1985) and Kilbom (1994); Green means safe, if no complaints are found. For lifting this means that applying the NIOSH 1991 equation the Maximal Permissible Limit (MPL) should not be exceeded. For pushing it is concerned safe if more than 90% (P90 = 90 percentile) are able to perform the task. Yellow means improvements are needed in time, and red means improvements are needed immediately.

3. RESULTS

3.1. Experienced Workload

Twelve bricklayers (all male, mean age 30 years, mean height 1.76 m, mean weight 76 kg) completed the questionnaire (response 48%). Six respondents had no history of back complaints, others had back complaints in the last 12 months. All respondents preferred bricks and mortar raised 50 cm, a significant difference. The work time for handlings was not influenced significantly (9 persons reported no difference, 3 reported faster is possible in the raised situation). The raised situation resulted in more comfort. The effects were largest in the lower back. In the raised situation the discomfort in the lower back decreased significantly (mean old discomfort in low back was 4.2, new 2.4, $p = .03$; see also Figure 3).

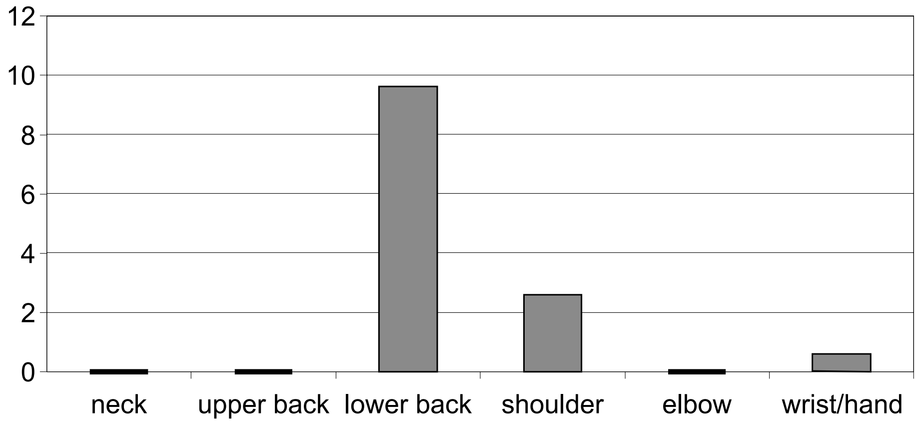

Figure 3. Body region where 12 bricklayers report more comfort while working with bricks and mortar 50 cm raised. Ten bricklayers report more comfort in the low back.

3.2. Estimation of L5/S1 Peak Loading

In Table 2 the measured angles are shown. All angles were influenced (see Table 2), especially the trunk. As was expected the trunk was significantly more upright working with the 50 cm raised bricks (difference 69.8º). This resulted in an estimation of the mean compression force of 2.3 kN traditionally and 1.6 kN working raised.

TABLE 2. Average Angles of 3 Participants (for Definition See Figure 4)

Body Region	Angle Working Traditionally (*SD*)	Angle Working 50 cm Raised (*SD*)
Shoulder	–88.9 (6.4)	–66.6 (7.4)
Elbow	–74.9 (5.0)	–38.1 (9.8)
Trunk	–5.9 (10.3)	63.9 (2.4)
Knee	116.8 (5.6)	99.9 (3.2)
Ankle	83.3 (3.1)	84.7 (1.3)

Notes. *SD*—standard deviation of the 21 recorded angles (3 participants × 7 measurements). All differences were significant ($p < .05$).

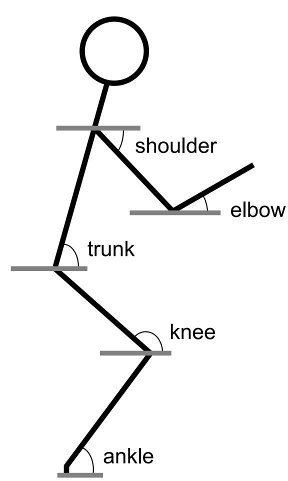

Figure 4. Angles (see Table 2).

3.3. Observation of Work

No differences in time consumption of the different tasks was found. The most important difference was found in trunk flexion. Table 4 shows the number of observations with a more than 20° or more than 60° flexed trunk. From the observations it was found that a traditional bricklayer bends his back more than 60° 3–4 times per minute during more than 4 hrs a day. This is evaluated as red (see table 1): a large health risk. In working with the 50 cm raised bricks the back is bent with the same frequency, but the flexion mostly does not exceed the 20°. Working with waal bricks of 17 N this situation is acceptable (green). However, working with bricks heavier than 20 N with a frequency of 5 per minute was sometimes found during a period of 2 hrs. This situation has an increased health risk according to the evaluation method used (yellow).

TABLE 3. Percentage of the Time Spent on Tasks of the Bricklayer Averaged Over 10 Participants

Tasks	Working Traditionally	Working With 50 cm Raised Bricks
Bricklaying	35	36
Isolating	7	6
Setting out horizontal line	10	11
Making window-frame anchors	4	7
Cleaning/communication	41	38
Removing mortar of brick	3	2

TABLE 4. Number of Observed Trunk Flexions During a Day Working With Waal Bricks Averaged Over the 10 Observed Bricklayers

	Trunk Flexion	
Setup	>20°	>60°
Working traditionally	912	842
Working with 50 cm raised bricks	211	12
Working with the bricklayer 50 cm lowered	42*	2*

Notes. *—only 2 participants.

Although hardly seen (2 participants in this study), the best results were obtained in the situation where the bricklayer positions himself 50 cm lower. In this case the bricks as well as the position in the wall are at a better working height.

4. DISCUSSION

Based on the results from all three experiments the hypothesis is rejected. All experiments indicate that 50 cm raised bricklaying is favourable. The bricklayers experience the work better, the lumbar peak load estimation on L5/S1 is lower in the raised condition, and observation of the work showed that working with raised bricks reduces the risk. However, the conclusions should be drawn with care as this study had only limited participants observed under nonstandardized conditions in a natural setting.

Each part of the experiments presented has its drawbacks:

- It was impossible to study the effects of each product (split scaffolding and shores) separately;
- The response is low in the questionnaire;
- The bricklayers completing the questionnaire could be biased as the new devices were promoted by the management with the motive to reduce musculoskeletal load;
- Only 3 participants could be found that had comparable work for biomechanical analyses;
- Dynamic work is analysed with a static biomechanical model;
- Only 10 participants were observed;
- Observations are evaluated with guidelines that still have a weak basis.

This study illustrates that experimental measurements in a naturalistic setting do have constraints. It is clearly not always possible to proceed along the rules of the experimental paradigm (controlling certain factors and at the same time manipulating others). Furthermore the validity of the evaluation of the loadings is uncertain. However, all three experiments point out the same direction and therefore this study is used to advise the bricklayers positively on implementing better ways of working.

Comparison with other studies on bricklayers strengthens the outcome. The fact that bricklaying is heavy work is described by Jørgensen, Jensen, and Kato (1991). The result that bricklayers bend 3–4 times per minute is comparable to a study among German bricklayers (Luttman, Jäger, & Laurig, 1991). Although there are large differences in the way of working, they established a frequency of 2.9 times per minute. Also in Germany, Jäger et al. (1991) calculated the compression forces and concluded that they are more acceptable when bricks are grasped from a minimal height of 0.5 m. The previous laboratory study (Vink & Koningsveld, 1990) showed a decrease in biomechanical loading of 21% (from

1.9 kN traditionally to 1.5 kN 50 cm raised at L3/L4), whereas in this field study a reduction of 30% was found.

Other measurements like oxygen uptake and EMG also support our results. Jørgensen et al. (1991) stated that the large number of repetitive trunk flexions resulted in muscular fatigue found in the EMG pattern. Oxygen uptake was also significantly lower in a 50 cm raised situation (Vink & Koningsveld, 1990).

However, despite the improvement caused by raised bricks and mortar, there is still room for improvement. The frequent handling in bricklaying (3–4 times per minute) and other tasks, like setting out, carrying, and cleaning have many possibilities for improvement. Also, the situation where the bricklayer positions himself 50 cm lower is preferable, which means that the scaffolding with the split floor should be promoted in combination with training how it should be used.

5. CONCLUSION

The major problem experienced by bricklayers is working between 0 and 50 cm above the floor. This study indicates that the problem can be reduced partly by heightening the bricks with shores or completely with scaffoldings that have the possibility of lowering the floor by 50 cm. Experiments and literature support this finding. Bricklayers experience the improvement as more comfortable and estimations of lumbar back load show a significant reduction. Also, observations evaluated with guidelines show a shift from unacceptable to acceptable. Moreover, further improvement to reduce the bending frequency and improve the other tasks of the bricklayer is advised.

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