Functional capacity evaluation

Reneman, M.F.; Joling, C.I.; Sloer, E.L.; Göeken, L.N.H.

Published in:
Work

Functional capacity evaluation: Ecological validity of three static endurance tests

M.F. Reneman[a,*], C.I. Joling[b], E.L. Soer[b] and L.N.H. Göeken[c]

[a]*Occupational Assessment Center Beatrixoord, The Netherlands*

[b]*Department of Movement Sciences, University of Groningen, The Netherlands*

[c]*Department of Rehabilitation Medicine, University Hospital Groningen, The Netherlands*

Received 5 May 2000

Accepted 27 June 2000

Functional Capacity Evaluation's (FCE's) are designed to measure the functional capacity of injured workers. Static endurance tests are integrated aspects of FCE's. Little is known about the validity of the tests. In this study, three static endurance tests (overhead work, crouching and kneeling) of the Isernhagen Work Systems FCE are studied for ecological validity. By manipulating the environment in an experiment using three different conditions (normal, loud noise, high production requirement), the ecological validity of the tests was investigated. Results: the different conditions did not seem to influence the holding times, the perceived exertion and the productivity of the subjects. The results are discussed and it is concluded that the three static endurance tests meet conditions of ecological validity. In order to be able to state that the tests of the IWS FCE are ecologically valid, more research is needed to enable a generalization.

Keywords: Occupational rehabilitation, work capacity testing, performance testing, postural tolerance, perceived exertion

1. Introduction

The rate of sick leave and the number of people on disability (1 million people out of 16 million inhabitants) in The Netherlands are high and still rising. Approximately one third of the people earning disability compensation are suffering from non-specific disorders of the musculosketetal systems. In 65–70% of the workers with a disorder of the locomotor system, a causal relation between the disorder and the job is supposed [7]. As a result of new legislation in The Netherlands, employers have become responsible for reintegration of disabled employees in the workplace. Furthermore, the employers have become liable for the financial risks of sick leave and disability. This involves considerable costs. Consequently, employers are interested in cost-reducing interventions. Some of these interventions occur in occupational rehabilitation and are often preceded by an assessment of the functional capacity of the disabled worker.

The basic philosophy in occupational rehabilitation is the concept that overuse injuries are caused by an ongoing disbalance between a person's functional capacity and functional demands [1,21]. As demonstrated in the load/capacity model in Fig. 1, every person, with his individual physical and mental capacity, fulfills tasks in a certain environment. A task leads to both a physical and mental load for the worker. Physical and mental demands and capacity influence each other, but are in turn influenced by the environment. In an optimal situation the total of capacities (functional capacity) is in balance with the total demands (functional demands). In the case of a disbalance, complaints such as non-specific low back pain will eventually start and probably continue until the balance has been re-established. From this point of view, a comprehensive assessment has to contain both functional load and functional capacity, as well as physical, mental and environmental factors [21].

Several methods of determining functional capacity are available. One of these is the Isernhagen Work Systems Functional Capacity Evaluation (IWS FCE), a well known method [12] used worldwide in approximately 700 facilities for occupational rehabilitation. The IWS FCE consists of 20 work-related tests, among which are tests that measure static postural tolerance. Three of these tests are "overhead work", "kneeling"

*Address for correspondence: M.F. Reneman, P.O. Box 30.002, 9750 RA Haren, The Netherlands. Tel.: +31 50 5338550; Fax: +31 50 5338550.

Work 16 (2001) 227–234
ISSN 1051-9815 / $8.00

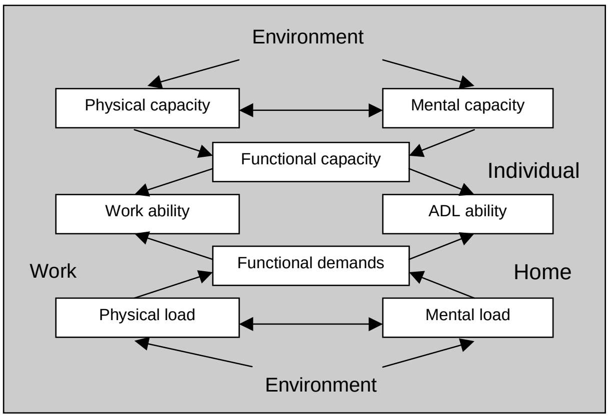

Fig. 1. Load-Capacity Model [24].

and “crouching”. With each test a certain criterion should be reached in order to be considered ‘normal’ or ‘within normal limits’. If a person does not reach the norm, this is considered to be a ‘limited’ performance. The norms used in this FCE are based on preliminary unpublished research [19]. Isernhagen collected data on 15,000 injured workers [10]. For the overhead work-test it is found that the average holding time for the uninjured population was 5 minutes. Individuals with limitations would terminate the test (far) before this time. Looking at both the uninjured and the injured population during the kneeling test, it seemed evident that 5 minutes is sufficient to identify physical limitations. A criterion of 5 minutes was set for both the overhead work and the kneeling test. The crouching test is not a tolerance test, but rather an activity that workers can or cannot perform. One minute was, therefore, chosen as the test duration. The performance standards of the three tests seem to be based on (a considerable amount of) experience, rather than on evidence. To our knowledge no research is published to the reliability and the validity of the tests that are the subject of this study. This finding of the lack of published research appears in concordance with the findings of authors that have conducted literature reviews on FCE’s in a more general sense [14,15,18,20, 23]. With regards to the overhead work testing, only one study is performed [22]. 44 Healthy young adults were tested per IWS FCE protocol, with the exemption of the fact that the subjects were asked to hold the posture as long as possible, rather than stop at a preset criterion of 5 minutes. The average maximum holding times were found to be much higher than the IWS FCE criterion (av. 16.18 min), with large variations between subjects. Test-retest reliability of this adjusted protocol was found to be high ($r = 0.716$).

The literature of adjacent disciplines, such as physiology, ergonomics and orthopedic medicine, was studied to find out whether the IWS FCE norms comply with knowledge generated there. In physiology it is known, that the bloodsupply in the muscles is insufficient when the strength of an isometric contraction is greater than 15% of the maximum voluntary contraction (MVC) [4]. The MVC is inversely related to the maximum holding time [13]. Isometric muscle contractions take place during static work and during the tests in question. At this point it is not known which percentage of the MVC is used during the three static endurance tests, thus norms can not be derived from force-time curves.

Specifically related to the subject studied, little is found in peer reviewed ergonomic literature. The overhead work test of the IWS FCE corresponds with one of the postures studied by Miedema et al. [17]. The average MHT is found to be 11.4 minutes. A discomfort of 2 on the CR-10 rating scale is considered as the maximum acceptable load. With and assumed linear relationship between perceived discomfort and the remaining holding time, it is implied that the overhead work posture should not be held longer than 2.3 minutes (20% of 11.4 minutes) in a working situation. The authors base their recommendations on average results of groups of healthy individuals. The relevance for FCE’s, where injured individuals are tested is likely to be limited. No other recommendations or guidelines were found in peer reviewed ergonomic literature.

Occupations in which people frequently kneel or crouch increase the risk of injury of the knees [5]. Compression forces in the knees rise when the thighs take a more horizontal position, as occurs during crouching [6]. Furthermore, crouching induces an unfavorable position of the knee joint and it could obstruct the

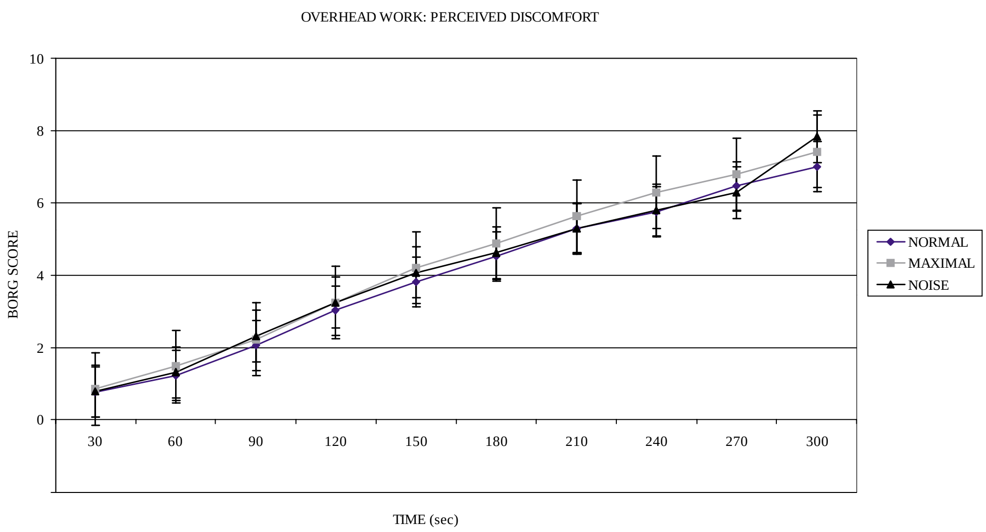

Fig. 2. Mean values of perceived exertion during the overhead work test under three different conditions.

Table 1
End values of perceived exertion (CR-10 ratings, av ± sd) on 3 tests under three different conditions

Condition	Overhead work	Crouching	Kneeling
Normal	7.0 ± 1.9	1.6 ± 0.9	2.9 ± 1.7
Maximal production	7.4 ± 1.7	1.7 ± 1.4	3.5 ± 1.9
Noise	6.8 ± 1.9	1.7 ± 1.0	3.4 ± 1.6

bloodsupply in the lower legs. It is recommended that the time spent in a kneeling or crouching position be limited [25]. The recommendations are not quantified by the authors.

Overall, based on the reviewed literature, it appears that there is limited knowledge specifically with regards to the validity of the studied postures. Taking this into account, a study was performed to investigate one aspect of the validity of the FCE: the ecological validity. Like all FCE's, the IWS FCE is performed under standardized conditions. Standardized testing implies that certain aspects of the work are not taken into account, such as environmental and organizational aspects. In this study the possible influence of two factors on the test results were investigated. By changing the conditions of the tests, the ecological validity, which is a form of external validity [16], of three of the static endurance tests of the IWS FCE (overhead work, crouching and kneeling) was investigated.

According to the load-capacity model (Fig. 1), the environment influences the physical and mental capacity, as well as the physical and mental load. For this reason, it seems likely that manipulating the environment could affect the holding times of the static postures required in the tests, as well as the production rate and the perceived exertion of maintaining these postures. One of the many aspects that encompass a real working environment is noise. The question investigated was, therefore: does the environmental aspect 'noise' influence the holding time, the perceived exertion and the production rate?

By using a standardized protocol organizational aspects, which are present in real working situations, are excluded. Demanding a maximal production implies an increase in physical and mental load. According to Huczynski [8] executing a task which causes a mental load requires motivation. If the environment causes a person to make more of an effort while working, this person will experience an increased mental load. The question investigated was, therefore: does a required maximal production influence the holding time, the perceived exertion and the production rate?

2. Methods

2.1. Subjects

In this experiment 24 subjects were tested, 12 males and 12 females. The following selection criteria were used: the subjects were students, 20–25 years old (means: men 21.8, women 21.5 years old) and all subjects declared to be healthy and able to perform the three static endurance tests at their own risk.

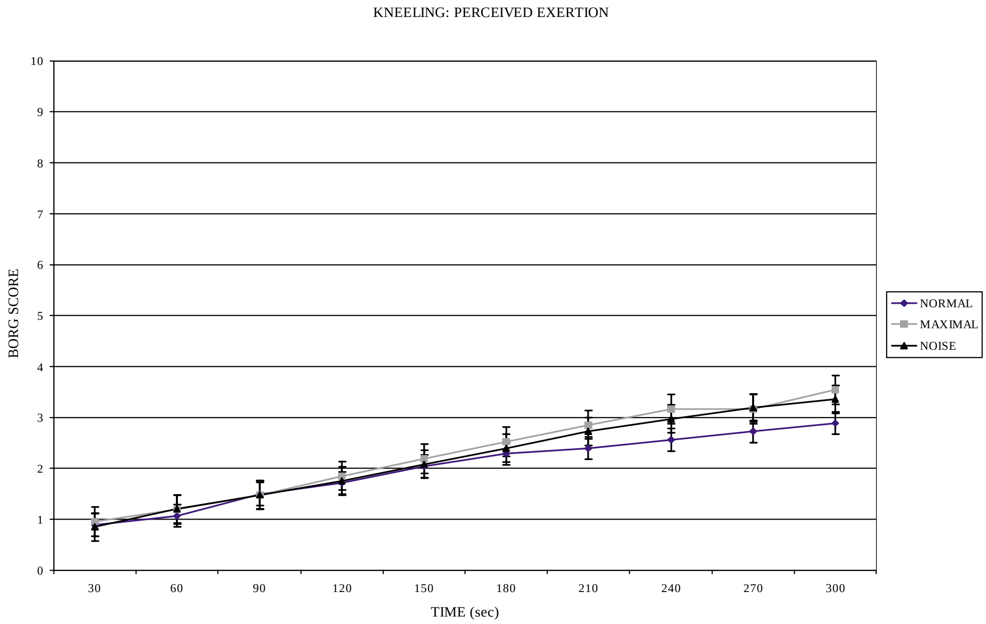

Fig. 3. Mean values of perceived exertion during the kneeling test under three different conditions.

2.2. *Instruments*

The following materials were used (per IWS FCE manual):

- overhead work: an aluminum plate adjustable in height with 20 holes, screws and nuts,
- kneeling: a table (height 76 cm), a box with screws and bolts and a piece of carpet,
- crouching: no specific materials needed.

Apart from the above, the CR-10 rating scale [2], a stopwatch and a walkman were used for this experiment. The CR-10 scale is determined to be a reliable, valid and practical instrument in the measurement of perceived exertion when applied to physical work [2, 3].

2.3. *Procedures*

The standardized protocols of the IWS FCE were used (IWS FCE Manual). Before starting the tests, the subjects were instructed on how to perform the tests. Overhead work test: the subject stood in an erect position. The height adjustable wall-mounted system was adjusted to the subject's crown height. The subject worked with hands at crown height, requiring 90° flexion at the shoulders and elbows. In this position, the screws/bolts were taken apart and reassembled. Kneeling was performed in an upright position with knees flexed and hips extended. In this position, the screws/bolts were taken apart and reassembled vice versa as well. Crouching: the subject sustained this position with full knee and hip flexion. No task was performed in this position. The subjects received instructions on how to use the CR-10 scale [2]. Dependent variables were: holding times, perceived exertion and production rate. Holding times were recorded in minutes and seconds, and transformed into seconds for analysis. The perceived exertion was rated and documented every 30 seconds.

The subjects performed the three static endurance tests under three different conditions (nine tests in total). All tests were performed in the same order: overhead work, kneeling and crouching. The subjects were tested under the following three conditions: normal (A), maximal production (B), annoying music (noise) (C). For normal conditions, the tests were performed according to the existing protocol of the IWS FCE, meaning that the subject manipulated screws/bolts at his own comfortable speed. The condition 'maximal production' involves the subject screwing as fast as possible. During the third condition 'annoying music' the subject wore a walkman with loud 'house-music' (cd: Thunderdome I). The volume was adjusted to such a level that the subject experienced it as acceptable but very annoying. A balanced design is used, in which the sequence of the conditions were alternated. Six different sequences were possible and used: ABC, ACB,

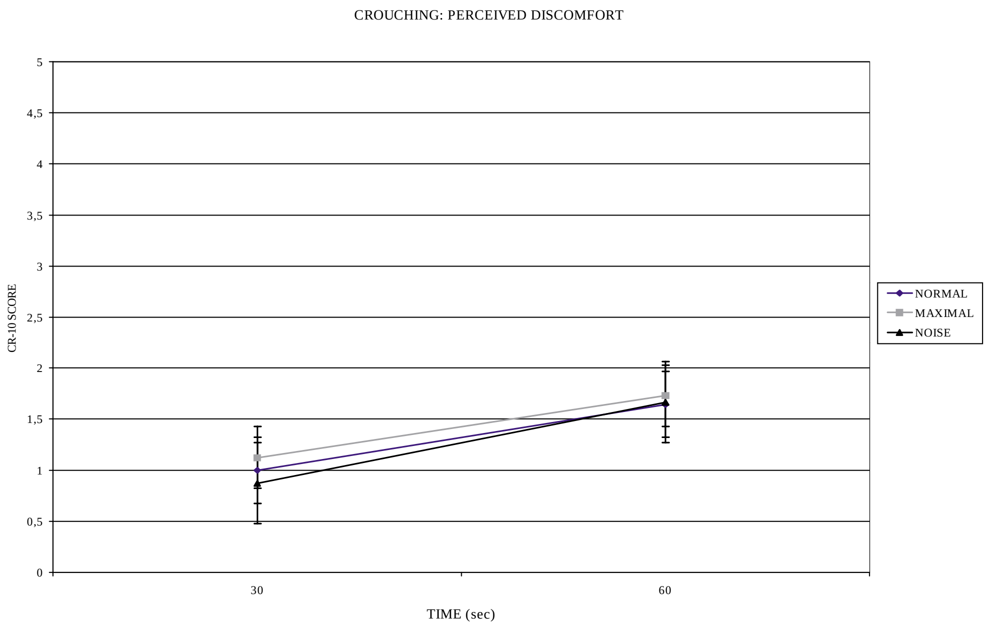

Fig. 4. Mean values of perceived exertion during the crouching test under three different conditions.

Table 2
Production rate (amount per minute, av ± sd) on 2 tests under three different conditions

Condition	Overhead work	Kneeling
Normal	6.6 ± 1.3	6.4 ± 1.0
Maximal production	7.3 ± 1.9	6.6 ± 1.2
Noise	7.0 ± 2.5	6.4 ± 1.1

BAC, BCA, CAB, and CBA. The subjects were divided by gender, after which they were randomly allocated to a certain sequence.

By inserting recovery intervals between the different conditions the effects of fatigue were reduced. The Recovery and Holding Times model [9] indicates that a relation exists between the needed recovery time and the holding time. This relation depends upon the amount of effort produced. It was assumed that crouching and kneeling belong to the category 'light effort'. The overhead work task falls between the categories 'light effort' and 'moderate effort'. To achieve adequate recovery, the following procedure was used: between the different conditions the subjects received a 5-minute rest interval and the subjects received 1 minute of rest between the three static endurance tests during each condition.

The following variables were entered in a database for analysis: age (years), gender (male/female), testing order (6 values), holding times (seconds), perceived effort at 30, 60, 90 etc. seconds (CR-10 rating), number of screws/bolts manipulated (amount per minute, overhead work and kneeling only). Statistics were performed using SPSS (Statistical Package for Social Sciences), using the General Linear Model (GLM), repeated measures. When significant differences were found, separate testing was performed to differentiate between the conditions (Student t-test).

3. Results

The influence of the three test conditions on the dependent variables (holding times, perceived exertion and production rate) are presented in this section.

3.1. Holding times

All subjects were able to complete each test under each condition (overhead work and kneeling: 5 minutes, crouching: 1 minute).

3.2. Perceived exertion

Perceived exertion under conditions "normal", "maximal production" and "noise" are presented in Table 1. The perceived exertion of the overhead work test was rated higher than the crouching and kneeling test. Mean values of perceived exertion increased with time (Figs 1–3). This applied to the three different tests as well as to the three different conditions. The perceived exertion (CR-10 scores) of the three conditions at the end of each test were compared.

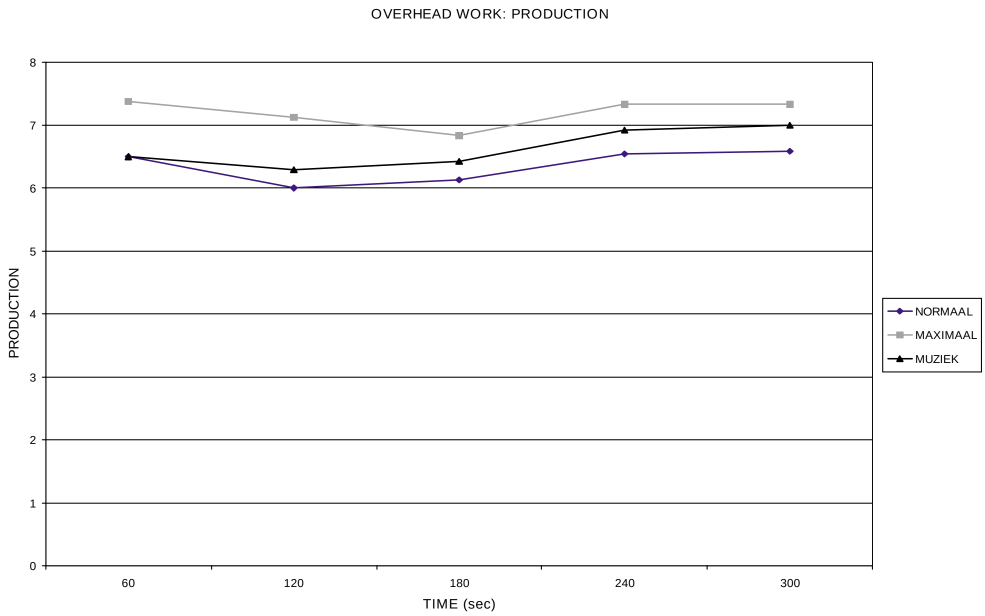

Fig. 5. Production rate during the overhead work test under three different conditions.

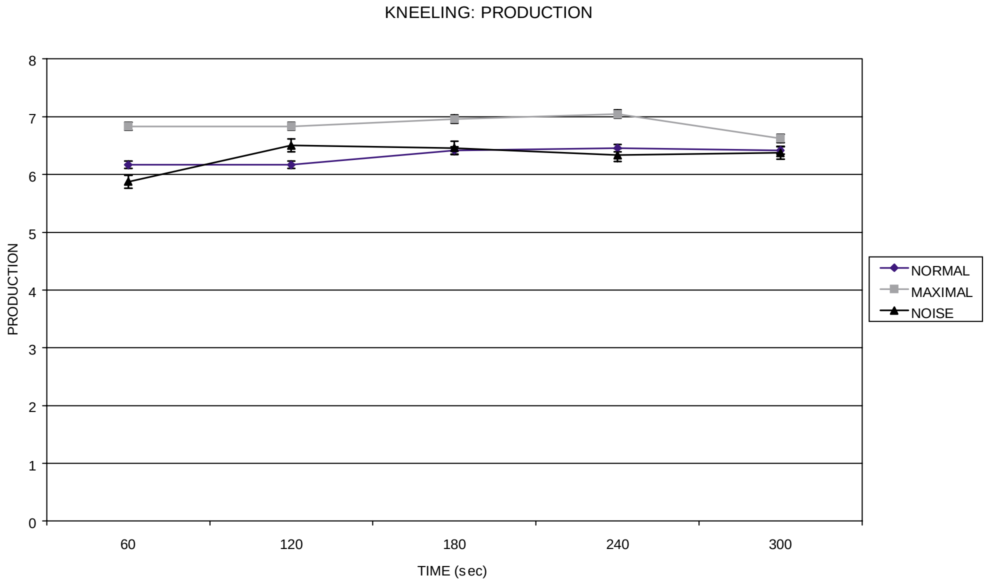

Fig. 6. Production rate during the kneeling test under three different conditions.

– Overhead work test: only slight differences in perceived exertion between the three conditions were found (Fig. 2). These differences in end values are not significant when maintaining an alpha (α) of 0.05. (MANOVA, $P = 0.128 > \alpha = 0.05$.)
– Crouching test: no significant differences between end values of the three different conditions were found ($P = 0.895 > \alpha = 0.05$).
– The kneeling test resulted in a significant ($\alpha < 0.05$) difference between the end values of perceived exertion of the three different conditions ($P = 0.034$). A paired t-test was then executed. With this test the values of the conditions "normal" and "maximal" proved to be significantly different ($P = 0.010$). The conditions "normal" and "noise" did not differ significantly ($P = 0.059$),

nor did the conditions “maximal” and “noise” ($P = 0.417$).

3.3. Production rate

Production rates per minute under the three different conditions are presented in Table 2 and in Figs 5 and 6. As expected, the productivity of the subjects is highest under the “maximal” condition. The differences in production rates between the three conditions are, however, not significant (overhead work test $P = 0.153$; kneeling test $P = 0.707$).

4. Discussion

With one exemption, neither one of the dependent variables used in this study (holding time, perceived exertion and production rate) are influenced significantly by the environmental factors ‘noise’ and ‘maximal production’. The one exemption is the difference in perceived exertion in kneeling between the conditions ‘normal’ (average CR-10 score of 2.9) and ‘maximal production’ (average CR-10 score of 3.5). The difference, although statistically significant, is considered to be too little to be relevant in a clinical situation. Consequently, the answer to the question studied appears to be affirmative: the tests studied do meet requirements of ecological validity. Just by meeting requirements of ecological validity, however, the FCE can not yet be considered ecologically valid. Before this generalization can be made, more research needs to be performed. For example, only three tests of the IWS FCE were studied. Generalizations to the other static endurance tests, or the FCE as a whole, are not possible from this research. Whether testing according to other FCE protocols would lead to similar results is not known. It is also not known if, or to what extend people in other age groups differ from the young adults tested here. Neither is it known if the testing of patients will lead to different test results. Other than the normal testing situation, only two of the many other possible environmental variables were selected for this study. Noise and maximal production alone cannot be expected to represent the stress encountered in a real working situation. Generalization to ‘the environment’ should not be made.

The time standards used in the IWS FCE (5 and 1 minutes) could be too short to have an influence on the functional capacity. The subjects knew beforehand that the tests only took 5 or 1 minutes. They were also informed on the procedures as a whole. Furthermore, the subjects were distracted every 30 seconds when rating their exertion. A stronger influence of environmental conditions on test results is expected when the subjects are asked to perform more strenuous activities. For example, a required holding time of 5 minutes in overhead work testing is less than half of the average MHT found by Miedema et al. [17] and less than a third of the average MHT found by Reneman et al. [22]. This implies that, even though the subjects rated their perceived exertion at 5 minutes to be ‘very heavy’ (6.8–7.4 on the rating scale), they were performing at an intensity level less than half of their maximum capacity. This may have enabled the subjects to cope with the situation to the extent that the holding times, perceived exertions and production rates were not influenced by differences in the environment. This in turn contributes to the observation that the measured output in performance testing (such as the ‘functional capacity’ in an FCE) is determined by physical and psychological factors [26] and contribute to the plausibility of the model presented in Table 1.

5. Conclusion

The main question in this study was: Do the three static endurance tests of the IWS FCE meet the requirement of ecological validity? By manipulating the task environment in this experiment, the ecological validity was challenged. The results indicate that the changes in environment, as described in this study, did not influence performance and perceived exertion. This leads to the conclusion that the tested static endurance tests, as performed in the IWS FCE, meet the requirement of ecological validity. In order to be able to state that the tests of the IWS FCE are ecologically valid, more research is needed to enable a generalization.

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