Gender in agriculture: requirements for operating forces on (agricultural) machinery

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Background

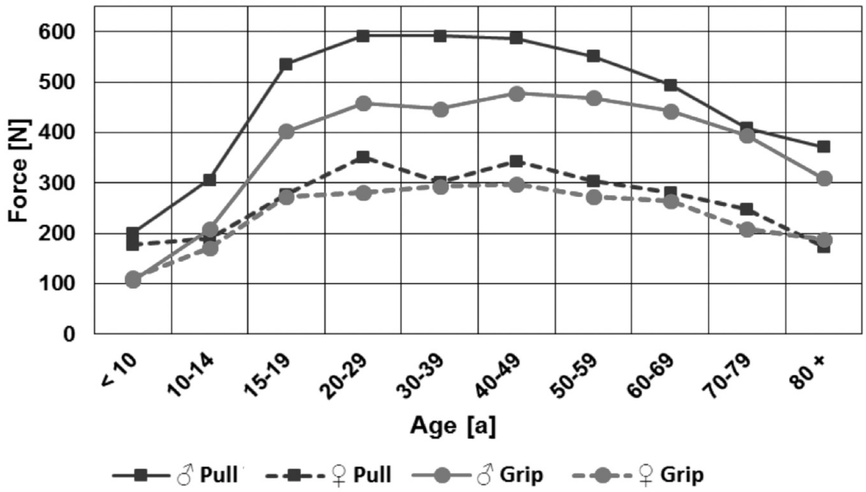
Agricultural machinery has developed a lot over the past few decades and has increased both in its dimensions and in the number of technological implementations. On some machines, the operations are mechanically assisted. However, on a significant percentage of machines, completely manual operations are still necessary. To operate levers, to swing hatches, covers and ladders into position and latch them there or to move other parts, the operators of agricultural machinery must exert certain forces.

Some examples on harvesters:

- the straw shredder has to be adjusted manually, which requires high forces;
- the corn tank has to be opened and closed manually, which also requires high forces;
- during maintenance, ladders have to be moved, side flaps to be opened and closed, and levers (which may have rusted over time) to be operated.

National and international standards on agricultural machinery (e.g. ISO 4254 (ISO 2013-2019)) make clear statements regarding the requirements of these machines. During a revision process of standards, the OSH (occupational safety and health) experts in the standardisation committee identified that the existing requirements concerning operating forces needed to be adjusted. Some standards state that the force to be exerted must not exceed 400 Newton (N). These forces of 400 N peak forces and 250 N average forces seem to exceed many operators' capabilities. Most women, for example, are on average unable to exert a force of 400 N (see Figure 1). In general, when evaluating maximum allowable operating forces, particular attention has to be paid to the effects of gender and age on the strength of operators. A study of Serafin *et al.* (2015) shows that on average women reach about 66% of the maximum strength level of men. It also has to be taken into account that strength decreases with age. In addition, the values stated in the standards have no (known) scientific basis. Nor, as yet, has a measurement method been described by means of which manufacturers or inspectors from governments could measure operating forces simply and cheaply, but nevertheless reproducibly.

Figure 1 **The effect of age and gender on pulling strength and grip strength (n=1,207)**



Source: In accordance with Serafin *et al.* 2015

To establish a solid base for defining the content of standards, the Commission for Occupational Health and Safety and Standardisation (KAN) commissioned a study on operating forces at the Institute of Occupational Health, Safety and Ergonomics (ASER) in Wuppertal (Germany).

Aims of the study

The aims of the study were:

1. To determine the current state of affairs concerning the science and technology used for the measurement of operating forces;
2. To develop and evaluate a practicable measuring procedure which makes it possible to measure operating forces on (agricultural) machines simply and cheaply, but nevertheless reproducibly; and
3. To examine whether the maximum acceptable operating forces (400 N peak and 250 N average) often mentioned in ISO standards for mobile agricultural machinery are appropriate (particularly with respect to the operator's gender) from an ergonomic point of view.

Methods

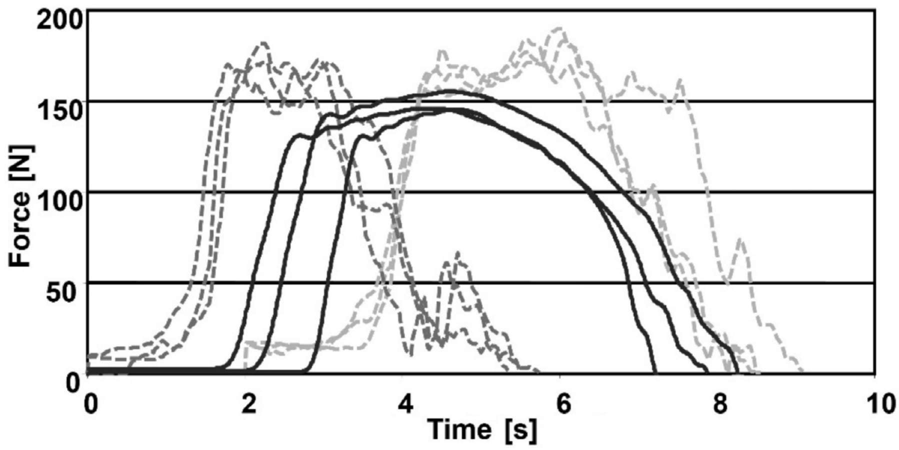
First, the project team examined a number of operating scenarios on agricultural machinery (levers, flaps, hoods, clamps, locking devices and other movable components etc.). A manual and an automatic measuring procedure for the determination of operating forces was developed (see Figure 2) and corresponding measurements were performed in different ways. The manual procedure involved a number of test subjects, equipped with hand-held force measuring devices, operating controls and moving parts in various different postures and with different directions of force exertion. To estimate the validity of the measurements performed in this way on test subjects, comparative measurements were performed with the aid of a winch connected through a force transducer to the handle or hatch of the operating element (automatic measuring procedure). Overall more than 700 repeated measurements of different operating elements were conducted in field and laboratory conditions. As measures of accuracy of the measuring procedures, repeatability and reproducibility have been determined in accordance with ISO 5725-2 (ISO 1994).

Furthermore, to determine maximum operating forces feasible for female and male operators, orienting measurements of maximum isometric body strength in typical postures assumed when operating agricultural machinery were conducted on eight subjects (four female and four male). Three cases of force exertion (lever actuation, opening/closing side flaps and locking a ladder), each in 3 to 15 positions distributed over the human handling area have been examined in more than 3,000 single measurements in 133 positions.

Figure 2 **Automatic (top) and manual measuring procedure with two examiners (bottom)**

Results

Figure 3 **Typical force-time diagrams of the manual procedure for three repeated measurements with two examiners (dashed lines, grey) and the automatic procedure (black) for the same test object**



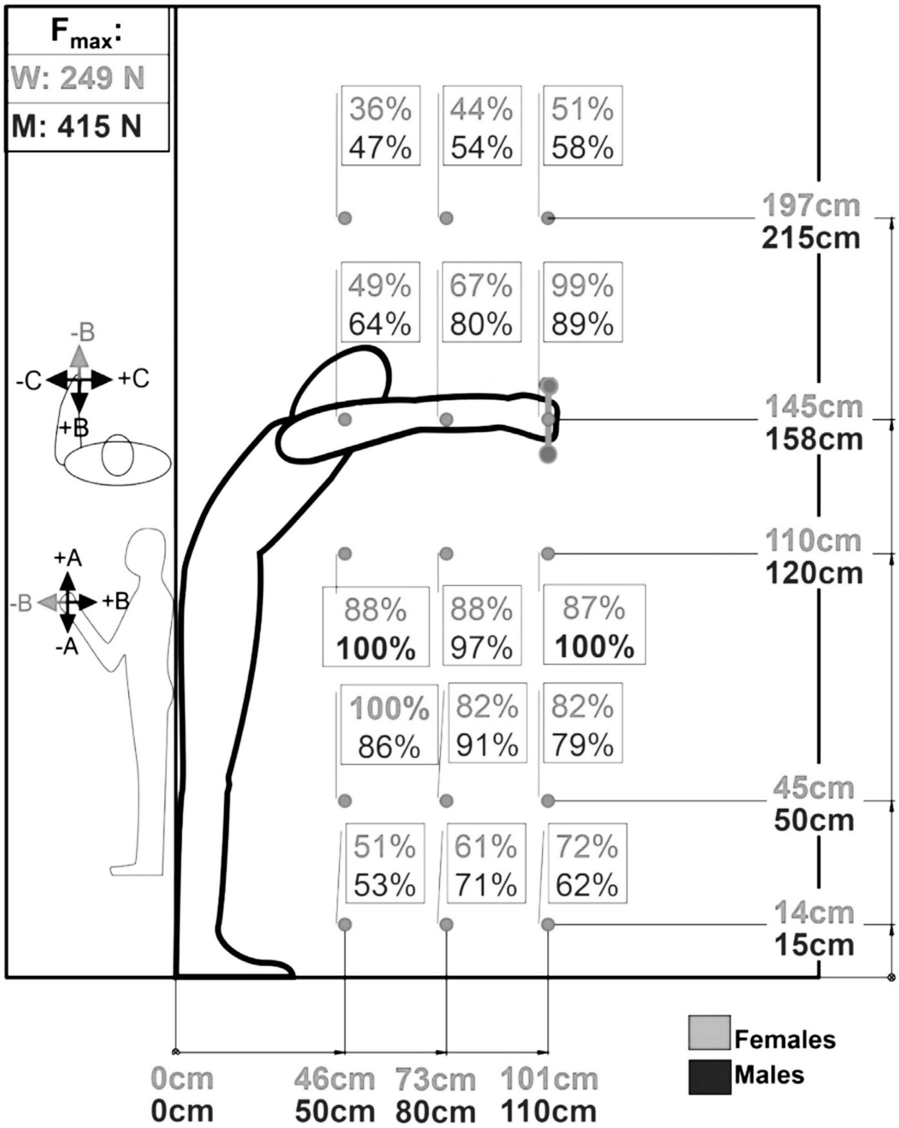
The averaged results for repeatability and reproducibility from all measurements done in laboratory conditions are shown in Table 1. Both measuring procedures primarily provide comparable results. The automatic procedure predominates in accuracy. The manual procedure is much easier to apply and still provides adequate, slightly higher results than the automatic procedure. Furthermore, tests have shown that the manual procedure requires practiced examiners in order to achieve accurate results.

Table 1 **Repeatability- and reproducibility-coefficient of variation (C.O.V.) averaged over all measurements of operational force in the laboratory**

	Average repeatability - C.O.V.	Average reproducibility - C.O.V.
Automatic procedure	2.8%	2.9%
Manual procedure	4.4%	6.6%

Maximum operating forces feasible for female and male operators are presented in Figure 4. Results show that female subjects reach considerably lower forces than male subjects (about 60%). Depending on the body posture, force direction and the individual properties of the operator population, it can be stated that maximum operating forces, mentioned in standards, are too high to be executed by most female and many male operators.

Figure 4 **Summary of one-handed pushing forces over the human handling area for women and men**



Note: Values expressed in percentage related to the maximum strength in the most favourable position (top left).

Discussion

The study confirmed the impression of the OSH experts, namely that the values stated in the standards are substantially too high, unless only particularly strong individuals are to be able to operate agricultural machinery. This means that the values should also consider female trainees or older workers on farms.

The scope of the study did not allow for definitive values for specific application scenarios to be determined which could be included in the standards. Owing to the limited body of data, the values determined can only serve as recommendations. For robust values to be obtained, the body of data would have to be considerably expanded.

The study nevertheless provides constructive recommendations for instruments and measurement techniques. Hand-held instruments that can be connected to a computer produce robust values. Owing also to their low cost, they could conceivably be used by mobile employees for the purpose of market surveillance as well as by accident insurance providers and manufacturers. The results of the study can also be applied to mobile machinery in other sectors, such as construction machinery.

Conclusions for standardisation and practice

The force values currently stated in agricultural machinery standards are too high. The priority now is for the approach described in the study to be developed further. Standardisation activity either requires robust values based on an extended body of data, or it must seek other solutions by which requirements can be formulated even in the absence of specific values, in order to enable all users of agricultural machinery to work with it safely and ergonomically.

The extensive report about this study is available on the KAN website in both German (Klußmann *et al.* 2013a) and English (Klußmann *et al.* 2013b).

References

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Annex

The task of the **Commission for Occupational Health and Safety and Standardisation (KAN)** is to monitor standardisation work from the occupational safety and health (OSH) perspective and to ensure OSH interests are reflected in standardisation.

The social partners, the state, the statutory accident insurance institutions and the German Institute for Standardisation (DIN) are represented in KAN. The commission 'pools' the opinions of the various OSH stakeholders (based on a broad consensus between all parties) and the resulting position is expressed in the form of comments and provided as input into current and planned standardisation projects or existing standards, via DIN. It also represents the opinion of the German OSH world in debates concerning standardisation policy. KAN itself is not, however, a standardisation body.

KAN was created in 1994. Responsibility for the commission lies with the Association for the Promotion of Occupational Safety in Europe (VFA) and financial support is provided by the Federal Ministry of Labour and Social Affairs. Its membership consists of the social accident insurance institutions for trade and industry and for the public sector.

Since 1976 the **Institute of Occupational Health, Safety and Ergonomics (ASER)** research group carries out basic and application-oriented research and development projects in the area of work, safety information and traffic sciences. His traditional fields of work include work-scientific analysis and the assessment and organisation of work, as well as basic research in the field of occupational sciences and safety in order to identify cause-and-effect relationships through field and laboratory studies. Research and development projects in the area of product development and product design are carried out with ergonomic, safety and occupational psychology goals in mind. Since the beginning of the 1990s an additional working field concerning the effective and efficient transfer of information and knowledge about work, safety and traffic sciences has been established for experts from small and medium-sized enterprises as well as for citizens, leading to the production of an innovative research network and lasting system developments.