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UNDERSTANDING STATIC MUSCULAR CONTRACTIONS AND BODILY MOVEMENTS

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ABSTRACT

The human body is able to move, because it has a widely distributed system of muscles, which together make up approximately 40 percent of the total body weight. The most important characteristic of a muscle is its ability to contract. Contraction is the means by which an internal expenditure of energy produces externally visible and measurable work. However, the muscles themselves are constrained by the limits of their strength and their ability to maintain that strength. When discussing any of these factors, a clear distinction must be made between the type of work which the muscle is called on to do, which is between static and dynamic work. During dynamic activity, the muscles contract and relax rhythmically. During the static activity, a muscle remains in a particular state of contraction for a long period, and so gives little external sign of doing useful work. During static contractions, the muscle is starved of oxygen, and waste products accumulate as oxygen-independent metabolic processes take place. Discomfort and fatigue occur rapidly during static contractions for this reason. Muscles can perform well-organized dynamic work easily, but they fatigue quickly in static efforts. Therefore avoiding static efforts, including standing or sitting still over long periods of time, is recommended. The present paper aims to explain the concept of static muscular contraction, its physiology, impact on work efficiency and ergonomically feasible solutions through review of existing literature.

KEYWORDS: Dynamic Work, Ergonomics, Muscles, Muscular Contraction, Physiology, Static Work, Work Efficiency

INTRODUCTION

Bodily movements and physical efforts are made possible in the first place by the operation of muscles. The most important characteristic of a muscle is its ability to contract: it can shorten it by up to half its normal length. Contraction is the means by which an internal expenditure of energy produces externally visible and measurable work (Grandjean, 1973). The work levels, which the human operator is called on to perform must clearly be within his physical as well his cognitive capabilities. This is the reason for discussing such aspects as anthropometrics and biomechanics. However, it is often forgotten that the muscles themselves are constrained in their ability to carry out the work. This is due in the first place to the limits of their strength and secondly on their ability to maintain that strength (in other words their endurance and their resistance to fatigue) (Murrell, 2012).

When discussing any of these factors a clear distinction must be made between the type of work which the muscle is called on to do, which is between static and dynamic work. This distinction is normally made in terms of whether or not motion accompanies the muscular tension. The work is said to be static if no motion occurs, for example, when holding a weight in the palm of the hand with the arm outstretched but not moving. If the arm moves up and down, however, then the upper arm and muscles are said to be doing dynamic work (Murrell, 2012).

STRUCTURE OF MUSCLE

The human body is able to move because it has a widely distributed system of muscles, which together make up approximately 40 percent of the total body weight. Each muscle consists of a large number of muscle fibers, which can be between 5 mm and 140 mm long, according to the size of the muscle. The diameter of a muscle fiber is about 0.1 mm. A muscle contains between 100 000 and 1 million such fibers. The fibers of long muscles are sometimes bound together in bundles. At each end of the muscle the sinews are combined into a tough, nearly non-elastic tendon, which ends firmly attached to a bony skeleton (Grandjean and Kroemer, 1997).

A complete muscle is made up of many bundles of fibers (cells) arranged side by side and covered by connective tissue. Each muscle fiber consists of many smaller myofibrils. A myofibril is split up into a number of sarcomeres arranged in series. A sarcomere consists of many filaments layered over each other in alternating bands. There are two types of filaments. Thick filaments consist of about 300 myosin molecules. Thin filaments consist of a globular protein called actin. The whole structure is bathed in intra- and extra-cellular fluid and is permeated by blood vessels and nerves (Bridger, 2008).

MUSCULAR CONTRACTION

The most important characteristic of a muscle is its ability to shorten to about half its normal resting length, a phenomenon we call muscular contraction. The work done by a muscle in such a complete contraction increases with its length: for this reason, we often try to prestretch a muscle before we contract it (Grandjean and Kroemer, 1997). The term muscle contraction refers to the physiologically active state of the muscle, rather than its physical shortening (Bridger, 2008).

During contraction, mechanical energy is developed at the expense of the reserves of chemical energy in the muscle. Muscular work involves the transformation of chemical into mechanical energy. The energy released by chemical reaction acts on the protein molecules of the actin and myosin filaments, causing them to change position and so bring about contraction (Grandjean and Kroemer, 1997).

The mechanism of muscle contraction consists of the actin filaments sliding over the myosin filaments (Gordon *et al.,* 1966). Since these filaments are arranged in overlapping, alternate bands, like a multilayered sandwich, sliding of the former over the latter causes the sarcomeres to shorten (the filaments themselves do not shorten). The primary stimulus for contraction is the release of calcium ions stored in the sarcoplasm. The calcium ions bind to the actin, which increases the affinity of myosin for actin (Bridger, 2008).

For a muscle to contract (that is, to do work) an extremely complicated chemical reaction is set up in the muscle itself. Described in its simplest form, the energy for the contraction is supplied by the breakdown of a chemical in the muscles called adenosine triphosphate (ATP) to adenosine diphosphate (ADP). However, the ADP must be regenerated to ATP before another contraction can take place, and the energy for this reversing action is provided by the breakdown of glycogen. Unfortunately, a byproduct of the glycogen breakdown is a poisonous substance called lactic acid. This is removed by a reaction with oxygen and converted into carbon dioxide and water. The function of oxygen, therefore is to convert the byproducts of the energy-producing reaction and this may continue for some time after the muscular activity has taken place. The role of the blood is to transport oxygen to the muscles and to remove the carbon dioxide and water (Murrell, 2012).

STATIC MUSCULAR CONTRACTION

Work physiology distinguishes between work when in motion (dynamic muscular activity) and work while stationary (static muscular activity). During dynamic activity the muscles contract and relax rhythmically. During static activity a muscle remains in a particular state of contraction for a long period, and so gives little external sign of doing useful work. The work of this sort can be compared with an electromagnet, which supports a given weight without movement, but with a steady consumption of energy (Grandjean, 1973).

Muscles are able to contract eccentrically, isometrically and concentrically. Eccentric contractions involve lengthening of an actively contracting muscle; concentric contractions involve shortening of the muscles while an isometric contraction (static contraction) is performed when a posture is maintained without any movement. (Bridger, 2008; Waters and Bhattacharya, 1996).

Blood flow is increased during dynamic work simply as a result of the pumping action set up by the muscles during the work. Blood is pumped through the blood vessels which supply the muscles, so helping the breakdown of lactic acid and removing the carbon dioxide and water. As long as the supplies of blood and oxygen can be maintained in sufficient quantities, therefore, and are not exceeded by the production of lactic acid, muscular fatigue is likely to be kept at bay. Under conditions of static load, however, no such pumping action occurs and the muscles soon become starved of the oxygen which they require. When this occurs, they are said to be in ‘oxygen debt’ (Murrell, 2012).

During sustained isometric contractions, the muscle is starved of oxygen, and waste products accumulate as oxygen-independent metabolic processes take place. Discomfort and fatigue occur rapidly during sustained isometric contractions for this reason (Bridger, 2008). The muscles fatigue rapidly under conditions of static loading even at a low workload (Kroemer, 1970).

The endurance time for maximum contractions is of the order of a second, 50% of maximum can be held for a minute or less. However, even though a static exertion such as standing with the arm fully extended at 90^o to the torso only requires 10% of maximum, musculoskeletal complaints will occur if the action has to be sustained all day at work (Parenmark *et al.,* 1988).

In general terms, static effort can be said to be considerably under the following circumstances:

- If a high level of effort is maintained for 10 s or more.
- If moderate efforts persist for 1 min or more.
- If slight effort (about one-third of maximum force) lasts for 5 min or more.

Constrained postures are certainly the most frequent form of static muscular work. The main cause of constrained postures is carrying the trunk, head or limbs in unnatural positions (Grandjean and Kroemer, 1997). When discussing fatigue, it is not commonly realized that the main muscles which do static work continuously are those in the back and shoulders, since they are involved in maintaining posture. Although they have more red muscle fibers than muscles which do dynamic work, they often run into an oxygen debt if a rigid posture is maintained for too long. This is particularly important to the seated operator (Murrell, 2012).

Our bodies must often perform static effort during everyday life. The onset of muscular fatigue from static effort will be more rapid the greater the force exerted i.e. The greater the muscle tension (Grandjean and Kroemer, 1997). A static effort which requires 50 percent of maximum force can last no more than 1 min, whereas, if the force expended is less than 20 percent of maximum, the muscular contraction can continue for some time (Moltech, 1963; Rohmert *et al.*, 1986). For these reasons work must be so planned, and workplace and domestic equipment must be so designed that static muscular effort is either eliminated or reduced to a point at which 20% of maximum effort is required. This is the most practical way of lightening the workload (Grandjean, 1973).

Under roughly similar conditions a static muscular effort, compared with dynamic work, leads to: a higher energy consumption, raised heart rate, the need for longer rest periods (Grandjean and Kroemer, 1997). A research by Malhotra and Sengupta (1965) showed that schoolchildren who carried their satchel in one hand needed more than twice as much energy as when they carried the satchel on their back. This increased energy consumption must be attributed to the high static loads on the arms, shoulders and trunk.

LOCALISED FATIGUE AND MUSCULOSKELETAL DISORDERS

Local muscle fatigue occurs when the endurance time for the muscle is exceeded. The endurance time for a muscle is dependent on the amount of force developed by the muscle as a percentage of the maximum force attainable by the muscle (Waters and Bhattacharya, 1996). Even moderate static work might produce troublesome localized fatigue in the muscles involved, which can build up to intolerable pain. If excessive static efforts are repeated over a long-period, first, light and then more intense aches and pains will appear and may involve not only the muscles but also the joints, tendons and other tissues. Thus long-lasting and often repeated efforts can lead to damage of joints, ligaments and tendons. These impairments are usually summarized under the term 'musculoskeletal disorders' (Grandjean and Kroemer, 1997). This indicates why a consideration of work-rest cycles, work durations, and forces are an essential part of the risk assessment process in job evaluation and injury prevention.

Table 1: **Static Load and Bodily Pains**

Work Posture	Possible Consequences Affecting
Standing in one place	Feet and legs; possibly varicose veins
Sitting erect without back support	Extensor muscles of the back
Seat too high	Knee; calf or leg; foot
Seat too low	Shoulders and neck
The trunk curved forward when sitting or standing	Lumbar region; deterioration of intervertebral discs
Arm outstretched, sideways, forwards or upwards	Shoulders and upper arm; possibly periarthiritis of shoulders
Head excessively inclined backwards or forwards	Neck; deterioration of intervertebral discs
Unnatural grasp of hand grip or tools	Forearm; possibly inflammation of tendons

Source: Grandjean and Kroemer, 1997

CONCLUSIONS

Muscles are the engines that drive our bodies. They convert chemical energy extracted from food and drink into mechanically useful force and travel of body limbs. Muscles can execute well-organised dynamic work effortlessly but they fatigue quickly in static work. Therefore avoiding static efforts, including standing or sitting still over long periods of time, is an important human engineering mission. Intermittent work is more beneficial than sustained static work with comparable workload. For comparable muscle contraction intensity, intermittent tasks can typically be performed longer, resulting in more work productivity. Apparently, regular breaks during static efforts allow for refurbishment of blood supply and ion fluxes. If a task requires a posture to be held for any length of time, posture analysis is needed by determining the mechanisms by which the posture is maintained, whether static muscular effort is essential, whether ligaments are being stressed, and whether parts of the work surface are providing support. Ultimately, it can be said that work which requires for the application of force over a long time period should be avoided. As far as possible all muscular activity should be intermittent, so as to allow the blood to flow through the muscle to reduce the probability of any oxygen debt building up, or to assist the paying back of a debt which has been incurred. Tasks that require continual contraction of muscles must be planned with working periods and rest periods so that the risk of accidents is not augmented through fatigue of the operators.

As a rule of thumb, for tasks requiring very high exertions, it is more efficient to lower the length of work periods and provide more frequent rest to prevent fatigue than to lower the work intensity. For low-intensity tasks, it is more efficient to lower the work intensity than to lower the length of the work period to prevent fatigue.

REFERENCES

1. Bridger, R. (2008). *Introduction to ergonomics*. CRC Press.
2. Grandjean, E. (1973). *Ergonomics of the Home*. Tayor and Francis.
3. Grandjean, E., & Kroemer, K. H. (1997). *Fitting the task to the human: a textbook of occupational ergonomics*. CRC press.
4. Jørgensen, K., Fallentin, N., Krogh-Lund, C., & Jensen, B. (1988). Electromyography and fatigue during prolonged, low-level static contractions. *European journal of applied physiology and occupational physiology*, *57* (3), 316-321.
5. Kroemer, K. E. (1970). Human strength: terminology, measurement, and interpretation of data. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *12* (3), 297-313.
6. Malhotra, M. S., & Gupta, J. S. (1965). Carrying of school bags by children. *Ergonomics*, *8* (1), 55-60.
7. Murrell, K. *Ergonomics: Man in his working environment*. Springer Science & Business Media, 2012.
8. Parenmark, G., Engvall, B., & Malmkvist, A. K. (1988). Ergonomic on-the-job training of assembly workers: Arm-neck-shoulder complaints drastically reduced amongst beginners. *Applied Ergonomics*, *19* (2), 143-146.
9. Rohmert, W. (1987). Physiological and psychological work load measurement and analysis. *Handbook of human factors*, 402-428.
10. Rohmert, W., Wangenheim, M., Mainzer, J., Zipp, P., & Lesser, W. (1986). A study stressing the need for a static postural force model for work analysis. *Ergonomics*, *29* (10), 1235-1249.
11. Waters, T. R. and Bhattacharya, A. (1996). Physiological Aspects of Neuromuscular Function. *Occupational Ergonomics: Theory and Applications*, (27), 63.