Review paper: Secular trends in human physical capacities of the working population and some ergonomic implications

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Abstract: The present review investigates the scope of secular changes in aerobic and anaerobic fitness and some factors that may modify these changes. The aerobic fitness shows considerable secular declines since the 1970s. These changes often show skew distributions due to impact of socioeconomic class, the largest decreases in the lowest classes commonly occupying the most demanding jobs. Some potential ergonomic implications are discussed.

Keywords: Secular trends, human physical capacities, ergonomic implications.

1. Introduction

During the recent century, extensive technical and organizational changes in working life have led to a dramatic reduction in the occurrence of traditional physically heavy jobs, particularly in terms of heavy lifting and high load on the cardiovascular system. In spite of this, several occupations still demand high cardiovascular and lifting capacities, i.e. high whole-body exposures. Examples are professional cleaning, healthcare and construction. In addition, high local physical demands (i.e. high local exposures) commonly occur in working life, e.g. work in prolonged and constrained postures. Furthermore, rationalizations of production systems may cause 'work intensification' (e.g. Docherty et al. 2002, Greenan et al. 2014), which may increase the exposures (Westgaard and Winkel 2011). According to this, occupational musculoskeletal disorders are still prevalent (e.g. Eurofound 2017) resulting in long-term seek leave and early retirement (e.g. Sundstrup et al. 2018).

Ergonomic interventions consider lack of balance between the specific physical job exposures and the physical capacity or fitness of the employee performing this kind of work (cf. Jørgensen 1985) in order to create 'sustainable work over the life course' (for definition see Eurofound 2015). From an ethical point of view, the exposure/capacity balance should primarily be created by reduction of the exposures. However, several reports indicate that the physical capacities of the working populations may have been reduced during recent decades. This could justify an increased focus on fitness training as part of ergonomic health promoting intervention programs. The present review aims to review the scope of secular changes of physical fitness and the significance of socioeconomic and geographic factors.

2. Methods

Our review focuses investigations of secular changes in aerobic (cardiorespiratory) fitness, anaerobic fitness and BMI.

Physical performance ability is commonly referred to as "physical fitness", which is an umbrella concept covering a series of qualities related to how well an individual performs physical activity (Åstrand et al. 2003). Physical fitness tests include one or more of the following aspects:

flexibility, speed, agility (neuromuscular fitness), aerobic fitness (maximal aerobic power, i.e. VO_{2max}) and anaerobic fitness including maximal anaerobic power, muscular endurance and maximal muscular force. Changes in Body Mass Index (BMI) is used as an indirect estimate of changes in physical fitness (McArdle et al. 2015). BMI categories according to WHO (World Health Organization): underweight <18.5 kg/m^2; normal weight: 18.5–24.9 kg/m^2; overweight 25.0-30.0 kg/m^2; obesity >30.0 kg/m^2.

The literature was mainly searched in Pubmed and Medline and was limited to studies published from 1979 to 2018. They contained data from 1890 to 2016 including both genders. Our analyses included 13-70 years old individuals. The following keywords and search profiles were used: (secular trend* OR secular change*) AND (maximal oxygen uptake OR aerobic capacity OR muscle strength OR muscle endurance OR muscl* power OR cardiorespiratory capacit* OR aerobic OR fitness OR physical work capacity OR aerobic power OR physical performance OR maximal power output OR cardiorespiratory fitness). Obesity studies without physical assessment were also included.

We included primarily original peer-reviewed papers in English. In addition, a few key reviews were included due to their comprehensive meta-analyses comprising relevant reports not published in peer-reviewed journals.

3. Results

3.1 Aerobic/cardiorespiratory fitness

The literature search identified 22 journal peer reviewed articles regarding secular changes of cardiorespiratory fitness from 13 countries. Additional 34 non-peer-reviewed papers were included in the reviews by Tomkinson et al. (2003) and Tomkinson and Olds (2007a, b) and as such included in the present review. In summary, these 56 studies showed secular declines of approximately 0,8 % p.a. since the 1970s. The data included adolescents as well as adults from both developed and developing countries (Craig et al. 2012, Dyrstad et al. 2005, 2012, Ekblom et al. 2011, Photiou et al. 2008, Tomkinson and Olds 2007a, Westerstahl et al. 2003). Earlier studies showed a more mixed pattern with increases (Tomkinson and Olds 2007a) and no or small declines (e.g. Andersen et al. 2010, Jonsson and Berggren 1979, Westerstahl et al. 2003). The same trends were frequently observed in both genders.

Santilla et al. (2006) showed differences in the secular changes according to socioeconomic class; in particular a faster impairment among “poor” performers, thus causing a skewed (“polarized”) distribution of aerobic fitness. Two large studies from the US included approximately 65 000 Euro-American subjects (20-64 y females, 20-74 y males) belonging to the middle and upper socio-economic strata. From 1970 to 2004/2009 the absolute VO_{2max} increased by 0,9% in females and 0,4% in males. This opposite effect was probably due to regular physical training and change in smoking habits (Li et al. 2015, Willis et al. 2011).

During 1980 to 2009 the European countries showed the similar secular changes in VO_{2max}. However, data from native populations in Mozambique and Canada (Inuits) showed that when their economic opportunities improved their aerobic fitness deteriorated markedly (Santos et al. 2015, Rode and Shepard 1994).

Conclusions: In general, the cardiorespiratory fitness shows a decline from mid-1970s. This decline was larger among the low-educated and economic weaker segments of the populations while the high-educated and more well-off showed no or slight increases.

3.2 Anaerobic fitness

The literature search identified 17 peer-reviewed articles regarding secular changes of anaerobic fitness from 13 countries. Additional 32 non-peer-reviewed papers were reviewed by Tomkinson (2007) and as such included in the present review. The latter included a meta-analysis of about 50 million 6-19 year olds from 27 countries.

In general, power and speed test performances have been relatively stable worldwide since 1958. This main conclusion was similar for boys and girls, children, adolescents and adults, different geographical regions as well as low and high-income economics. Thus, Ekblom et al. (2007) showed no secular changes in abdominal strength and endurance. A few studies deviate from this general picture. Heebøll-Nielsen (1982) found among 7-17 year old boys and girls that maximal isometric muscle strength in 8 different trunk and limb synergies a decrease by 8-10% from 1956 to 1981. Silverman (2015) found no secular change in grip strength among children, but among grown-up a secular decline that increased with age. A review of 15 studies on maximal isometric back muscle strength using identical measuring procedures showed marginal secular reductions (reviewed by Jørgensen 1997). Rode and Shephard (1994) investigated grip and leg extension forces among adult Inuits during a 20-year period of rapid acculturation to a sedentary lifestyle. They found strength reductions from 7% to 45% depending on age.

Conclusion: In general, the secular trend of anaerobic fitness shows in general no or marginal decreases.

3.3 Body Mass Index (BMI)

The literature search identified 52 peer-reviewed articles regarding secular changes of BMI from 24 countries. Additional 5 papers were identified presenting meta-analyses of data from 1 to 200 countries. Thus, the NCD (Non-Communicable Disease) Risk Factor Collaboration study (2017) comprised 200 countries, and 97.4 million males and females ≥20 y. Our BMI literature search was not exhaustive.

The NCD Risk Factor Collaboration study (2016) showed a global age-standardized mean BMI increase from 1975 to 2014 of 11.5% among men and 10.4% among women. The rising trends in adolescents' BMI seem to have plateaued at high levels in many high-income countries, but have further increased in central parts of Asia, Latin America and Oceania (Finucane et al. 2011, NCD Risk Factor Collaboration Study 2016, Rode and Shephard 1994, Santos et al. 2015). In USA 72.3% of the males and 64.1% of the females showed overweight or obesity with no significant increase after about year 2000 (Flegal et al. 2010). In contrast, underweight remains prevalent in the world's poorest regions (NCD Risk Factor Collaboration study 2016).

Overweight has increased in most low- and middle-income countries, but the increase differs between regions (Lopez-Arana et al. 2014). In Western Europe and high-income English-speaking countries and in Asia-Pacific high-income regions the mean BMI has recently flattened out for both genders (Finucane et al. 2011, NCD Risk Factor Collaboration Study 2017).

BMI seems particularly to increase in occupational groups of low to middle socioeconomic and educational levels (e.g Christine et al. 2014, Flegal et al. 1988, Grossschädl and Stronegger 2012, Lopez-Arana et al. 2014). Furthermore, Moreno et al. (2000) found a faster secular increase in BMI among those initially showing highest BMI, thus increasing the skewness ("polarization") over time.

Conclusions: In general, the secular trend of global average BMI seems to increase. In some high-income regions, however, BMI flatten out after about year 2000. Conversely, BMI increases continuously in low-income populations with low educational levels.

4. Discussion

4.1 Methodological considerations

The measurements of the physical fitness parameters presented in the reviewed papers represent a wide range of methods hampering more detailed comparison between studies. The physical fitness is estimated by i.e. bicycle ergometry, dynamometry, various running and jumping tests and the BMI. Furthermore, the ergonomic relevance of these data may vary according to specific physical job demands.

The anaerobic capacity was estimated in terms of e.g. power, strength and speed, and these parameters were, in turn, assessed using a broad variety of methods. Thus, comparison between studies regarding anaerobic capacity seems even more challenged than comparison between studies of aerobic fitness. Due to these limitations, our conclusions are limited to major trends only.

BMI has been used as an estimate of physical fitness. An increase in BMI may indicate reduction in relative Vo_{2max} (i.e. per kg body weight) and high jump results, while the absolute Vo_{2max} may be unaffected (Tomkinson et al. 2003, Venckunas et al. 2017). The validity of secular changes in BMI may thereby depend on the type of applied test. Thus, assessments based on movement of the whole body (e.g. 400 m run) may be influenced by increased BMI, but not the static muscle strength.

4.2 General discussion

In general, the secular trend of cardiorespiratory fitness shows a decline from mid 1970s. This trend depends on socioeconomic and geographic factors. Conversely, the anaerobic fitness shows no or only marginal decreases during the same period.

Physical fitness depends on age, gender and size as well as level and duration of physical activity during leisure time (Asmussen and Hohwü-Christensen 1983, Åstrand et al. 2003). In low-income populations, the educational level is often modest (Lopez-Arana et al. 2013). Thus, sufficient knowledge regarding lifestyle factors, such as nutrition and physical activity is lacking. This may imply that such populations are obvious candidates to low physical fitness and high BMI values when their access to cheap and unhealthy food and drink is increased. The dramatic secular decreases of aerobic fitness and increases in BMI in Mozambique and among Inuits in Canada (Santos et al. 2015, Rode and Shephard 1994) are presumed consequences of the above-mentioned life-style factors. In general, BMI and other measures for fat-mass have increased markedly in large parts of the world (NCD risk factor collaboration Study 2016), whereas the fat free mass seems to be stable or gently decreasing (Finucane et al. 2011, NCD risk factor collaboration Study 2017).

The different trends in aerobic and anaerobic fitness are not easy to understand. Tomkinson (2007) presents one possible explanation: “In distance running or other whole-body activities, the positive effect of increasing fat-free mass is not enough to match the negative effect of increasing fat mass, hence the declines over time. On the other hand, for sprint running and explosive jumping, the positive effect of increasing fat-free mass counteracts the negative effect of increasing fat mass, hence the relatively stability over time”.

4.3 Ergonomic discussion

It may be argued that the secular decreases in physical capacities should primarily be met by offering physical training of the individual workers. This seems further motivated as some studies

indicate that those in the most demanding jobs often have the lowest physical capacities (e.g. Karlqvist et al. 2003).
Sjögaard et al. (2016) have reviewed the effectiveness of different tailored exercise programs in terms of improved health. They concluded that physical training at the workplace tailored to work exposure, employee health status, and physical capacity may improve health. This was documented for jobs demanding high whole-body (e.g. construction workers) as well as local exposures (e.g. computer workers and dentists). It is, however, an ethical issue how to balance between interventions focusing job demands and individual capacities. Individualized physical training may be easier to implement than interventions reducing job demands. Nevertheless, interventions coping with the ongoing "work intensification" in working life (Westgaard and Winkel 2011) should be included as a significant part of an intervention program, thus allowing also the weaker people to enter the labor market.

5. Scientific conclusions

- Cardiorespiratory fitness shows considerable secular declines since the 1970s.
- The secular changes in physical fitness often show a polarization according to socioeconomic class; the largest decreases in the lowest classes commonly occupying the most demanding jobs.

6. Practical ergonomic implications

- The balance between occupational physical job demands and the physical capacity or fitness of the employee is a key issue of ergonomic interventions. It is an ethical issue where to put the focus.
- Some researchers have investigated and suggested tailored physical training programs to reduce negative health impact in cases of poor match between physical capacity and occupational demands.

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