IMPACT OF HIGH INTENSITY STRUCTURED EXERCISE ON DAILY PHYSICAL ACTIVITY AND SPECIFIC PHYSIOLOGICAL ADAPTATION

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Marja Uusi-Vähälä (2018): Kovatehoisen suunnitellun liikunnan vaikutus päivittäiseen fyysiseen aktiivisuuteen ja fysiologisiin muutoksiin. Jyväskylän yliopisto, pro gradu –tutkielma, s. 75, 4 liitettä.

Fyysinen aktiivisuus on jatkumo kevyestä aktiivisuudesta kovatehoiseen liikuntaan ja sen vaikutukset terveyteen, fyysiseen toimintakykyyn ja kuntoon ovat hyvin tunnettuja. Toisaalta myös fyysisen inaktiivisuuden ja elämäntavan tiedetään aikaansaavaan terveydelle haitallisia muutoksia, myös henkilöillä, jotka täyttävät fyysisen aktiivisuuden suositukset. Päivittäinen vaihtelu fyysisessä aktiivisuudessa yksilöiden välillä on suurta. Tutkimuksen tarkoituksena oli selvittää miten reisilihasten lihasaktiivisuus (EMG) eroaa 50 minuutin voima- ja intervallijuoksuharjoituksen, ja samanmittaisen lepojakson välillä. Lisäksi tutkittiin harjoitusten vaikutusta koko päivän fyysiseen aktiivisuuden tasoon. Lisäksi tarkoituksena oli selvittää harjoituksen aikaisen sekä päivittäisen aktiivisuuden merkitystä fysiologisessa adaptaatiossa.

Kymmenen koehenkilön (5 miestä, 5 naista) lihasaktiivisuutta mitattiin päiväkohtaisilla EMG-mittauksilla kolmena eri päivänä: voimaharjoittelupäivänä, intervallijuoksupäivänä sekä päivänä ilman suunniteltua liikuntaa. Voima- ja intervallijuoksuharjoituksia sekä päiviä, joihin harjoittelu sisältyi, verrattiin keskenään sekä päivään ilman harjoitusta. Harjoittelun intensiteetin yhteyttä päivittäiseen fyysiseen aktiivisuuteen sekä muutoksiin maksimivoimassa ja 3000 m juoksuajoissa tutkittiin vertailemalla eri intensiteettitasoja. Tutkimuksessa havaittiin, että voimaharjoitus ($p=0.002$) sekä intervallijuoksuharjoitus ($p<0.001$) vähentävät inaktiivisuutta sekä lisäävät lihasaktiivisuutta kaikilla tasoilla verrattaessa samanpituiseen jaksoon lepopäivänä. Molemmat harjoitukset nostivat merkitsevästi keskimääräistä EMG amplitudia (voimaharjoitus $p<0.001$ ja intervallijuoksuharjoitus $p<0.001$). Voimaharjoituksella ja intervallijuoksuharjoituksella todettiin olevan erilaiset aktiivisuusmallit. Päivätasolla havaittiin vain voimaharjoituksen vaikuttavan keskimääräiseen EMG amplitudiin ($p=0.018$) sekä nostavan erityisesti kovatehoisen aktiivisuuden määrää ($p=0.026$). Sekä voima- että intervallijuoksuharjoituspäivänä oli vähemmän inaktiivisuutta ja enemmän fyysistä aktiivisuutta kuin lepopäivänä, mutta ei merkitsevästi. Tämä oli yleinen trendi, yksilöerot liikuntavasteessa ja aktiivisuuden uudelleenjaossa ovat suuria. Kovatehoisen harjoittelun todettiin parantavan koehenkilöiden maksimivoimaa keskimäärin 9.8% ($p=0.008$) ja 3000 m juoksuaikoja keskimäärin 4% ($p=0.014$) 10 viikon harjoittelun aikana.

Tutkimuksen tulokset viittaavat siihen, että suunniteltu kovatehoinen harjoitus ei lisää päivän aktiivisuutta merkittävästi ja inaktiivisuusaika dominoi myös suunniteltuun harjoitteluun osallistuvien päivittäistä aktiivisuutta. Lyhyillä kovatehoisilla harjoituksilla saadaan kuitenkin aikaan fysiologisia vasteita.

Avainsanat: fyysinen aktiivisuus, inaktiivisuus, voimaharjoittelu, intervallijuoksuharjoittelu, lihasaktiivisuus, EMG

ABSTRACT

Marja Uusi-Vähälä (2018): Impact of high intensity structured exercise on daily physical activity and specific physiological adaptation. University of Jyväskylä, Master's thesis, pp. 75, 4 appendices.

Physical activity over the whole continuum from light activity to high intensity exercise is known to have beneficial impact on individual's health, physical capacity and fitness. Inactivity and sedentary lifestyle is also known to have detrimental consequences, even on individuals meeting physical activity recommendations. The daily variation in the physical activity patterns of individuals is high. The purpose of this study was to examine how muscle activity (EMG) in tight muscles differs between 50-minute strength exercise and interval running exercise and comparable rest period. Further, this study examined the impact of structured high intensity exercise on the daily the activity patterns and how physical activity impacts the changes in maximum strength and 3000 m running time.

The muscle activity patterns of ten individuals (5 men, 5 women) were studied with day long EMG measurement for three different days; one with strength training session, one with interval training session and one without structured exercise session. Strength and running sessions were compared with rest period equal length and the days with structured exercise sessions were compared with the day without exercise session. The effect of exercise intensity on activity patterns and on physiological adaptation was examined by comparing different activity levels. This study showed that an exercise bout of either strength training or interval running lessens inactivity (strength $p=0.002$ and interval running $p<0.001$) and increases muscle activity at all levels compared to similar rest period. Both exercises were increased the average EMG amplitude (strength training $p=0.002$ and interval running $p<0.001$). On the day level, strength training increased the overall EMG amplitude ($p=0.018$) and high muscle activity ($p=0.028$) in particular, when compared to the day without exercise. Both strength training and interval run training days had less inactivity and more light, moderate and high activity than resting day. This was the general trend however, response to exercise and the redistribution of EMG intensities is highly individual. High intensity exercise was also found to improve subjects' maximum strength by 9.8% ($p=0.008$) and 3000 m running times by 4% ($p=0.014$) during the 10-week training intervention.

The results of this study suggest that high intensity structured exercise does not increase the physical activity significantly but also is not compensated as an increase in the sedentary time of healthy young adults. This study shows that muscle inactivity dominates the daily activity patterns even with individuals participating in well-designed exercise programs.

Keywords: physical activity, inactivity, strength exercise, interval running exercise, muscle activity, EMG

ABBREVIATIONS

EMG:	electromyography
MET:	metabolic equivalent of task
PA:	physical activity
RUN:	interval running session or day
REST:	rest period or day without structured exercise
STR:	strength training or day

CONTENT

1 INTRODUCTION

When human body is challenged with physical tasks it responds through integrated changes that involve most of its physiological systems. Activation and control of the musculoskeletal system is required for a movement, whereas cardiovascular and respiratory systems enable this movement over extended periods. When an individual engages in physical activity or exercises frequently the bodily systems undergo specific physiological adaptations. The changes are largely dependent of the intensity and duration of activity bouts and the individual's baseline fitness level. But human body also reacts to inactivity. Removal or lack of stimulus by a physical task may result in loss of capacity gained and various health related problems.

Physical activity is one of the most key behavioral factors influencing the overall health, all-cause mortality and quality of life, and the association between physical activity and health in variety of populations has been demonstrated over the years in numerous studies (Strath et al, 2013; Reiner et al. 2013). The benefits to health caused by sustained moderate-to-vigorous physical activity (MVPA) well known and established (Powell et al. 2011; Garber et al. 2010), Results from various studies have demonstrated that individuals who are at least moderately fit have a substantially lower risk of morbidity and mortality and low fitness (level) is seen as one the strongest predictors of mortality (Haskell et al. 2009; Warburton et al. 2006). The list of exercise-induced health benefits across body's physiological functions has grown over the years. However, more recent research has also shown that non-exercise type of physical activity is also important to health (Ekblom-Bak et al. 2014). At the same time modern society provides more opportunities for more sedentary options and behavior resulting in increased sitting time and reduction in volume of physical activity. Only minority of individuals meet the recommended physical activity levels. These trends together constitute a threat to the health of individuals. (Blair & Morris, 2009.)

There are health benefits introduced by acute and chronic physiological changes orchestrated by physical activity. There are multiple mechanisms that the health benefits are achieved by, some of them unknown. In part, the benefits are mediated by physical activity (exercise) induced metabolic and molecular remodeling of skeletal muscle. Training mode, volume, intensity and frequency define the actual functional outcomes of physical activity. (Egan & Zierath, 2013.). It is known that training adaptations are specific to exercise training stimulus, and the responses of aerobic and strength training are very different as they represent different ends of the exercise continuum. Strength training generally refers to exercise aiming at improving strength and producing muscle hypertrophy, commonly comprising high intensity, short lasting contractions that fatigue muscles. (Murton & Greenhaff, 2013.). Endurance training consists usually of repeated and continuous skeletal muscle actions that last for prolonged periods at submaximal speed or power output and it is aimed at improving aerobic capacity of an individual (Hawley 2009).

Many studies have also concluded that time spent inactive, light-intensity physical activity and exercise time are independently associated with health parameters (Owen et al. 2012**)**, in other words, there are different health outcomes induced by sedentary behavior and distinctive types of physical activity (Powell et al, 2011). There is also evidence that the physiology of inactivity is unique and has biological processes operating that are different and separate from exercise physiology (Owen et al 2010). Research has provided evidence that chronic sedentary behavior leading to lack of muscle contractions in large muscle groups can lead to diminished aerobic capacity and muscle strength, loss of muscle and metabolic function (Lyden et al. 2014.) It has also been suggested that participation in purposeful exercise is independent of sedentary behavior and that sedentary behavior is not same as exercising too little, as sedentary time usually replaces non-exercise physical activity embedded into normal daily life (Levine 2002).

As skeletal muscle has pivotal role in physical activity, exercise and physiological responses, it is important to understand and know what kind of muscle activity and intensity there is throughout normal daily life and during an exercise bout. With exercise interventions and overall physical activity recommendations, it is also important to recognise how an individual’s physical activity behaviour changes during days with and without intentional, planned exercise. It is essential to get more evidence on how exercise modifies the dose of physical activity and inactivity as it can have large impact on individual adaptiveness.

2 PHYSICAL ACTIVITY AND HEALTH

Health-enhancing physical activity has been commonly defined as any type of activity that, when added to baseline activity, will bring health and fitness related benefits without unnecessary risk or injury to individual (Foster 2000). Regular physical activity has been associated with both physical and mental health benefits, both in men and women (Garber et al. 2011). Data from studies support the evidence that physical activity, exercise training and improvements in physical fitness are essential elements in treatment and prevention of many chronic diseases, especially life-style induced diseases (non-communicable diseases: cardiovascular diseases, chronic respiratory diseases, obesity, cancer, and diabetes) prompted by the environment that no longer obligates physical exertion of individuals (Reiner et al. 2013). Physical fitness has been seen as a stronger predictor of health outcome than physical activity, but a low level in both is a strong predictor of death (Warburton et al. 2006).

The purpose of this chapter is to introduce the basic concepts and to provide an overview on the relationship between physical activity and health and the related physiological mechanisms.

2.1 Components of physical activity

Physical activity has been commonly defined as any bodily movement produced by skeletal muscles with energy expenditure above resting level (Caspersen et al. 1985; Howley 2001). This term is commonly used when describing health enhancing physical activity (Strath et al. 2013). Bodily movement by skeletal muscles is caused by physiological process of muscle contraction. Muscle action is eventually caused by so called excitation-contracting coupling, a mechanism where an electrical discharge at a muscle initiates the events. Skeletal muscles are under voluntary control, and as such, in order for muscle contraction to occur, there must be a neural stimulus. Calcium in the muscle cell has important role in the contractile and metabolic activity and for muscle contraction to happen ATP available for energy is needed. (McArdle et al. 2010, 367-368.).

To understand sub-categories of physical activity, it is important to understand the relationship with *energy expenditure*. Physical activity is commonly quantified as the energy that is required to undertake an activity and is measured in kilojoules (kJ) or kilocalories (kcal). The amount of energy expenditure for physical activity can vary from low to high and it is determined by individual’s muscle mass (producing the movement) but also intensity, frequency and duration of muscle contractions. (Caspersen et al. 1985.) The total energy expenditure consists of resting metabolic rate (sometimes also called basal metabolic rate, which does have slightly different meaning), the thermic effect of food and the energy expenditure related to physical activity, including exercise. In inactive people the resting metabolic rate can account for about 60% of the total daily energy expenditure, usually it varies between 50 – 85% (Levine 2002; Lam & Ravussin, 2016). The thermic effect of food accounts for 10-15% and the energy cost of physical activities ranges from about 15% up to 50% (Lam & Ravussin, 2016; Pettee et al. 2012). Physical activity is the most variable component of the three (Pettee et al. 2012). Another way to classify physical activity by energy expenditure is through METs (Metabolic Equivalent of Task). MET is a physiological measure that describes the energy cost related to physical activity and is defined as metabolic rate during particular activity to a reference metabolic rate. The reference rate of 1 MET is considered the resting metabolic rate for an average person obtained during quiet sitting. The MET rates vary from 0,9 (sleeping) to 23 (running at high speed) and is used as means of expressing energy expenditure and intensity of activity in a comparable way among persons of different weight. (Ainsworth et al, 2000.).

Physical fitness (level) can be defined as the ability to perform daily activity with energy and vigilance, without undue fatigue (Caspersen et al. 1985). Physical fitness can be seen as a set of attributes that an individual has or can achieve and there are number of measurable components contributing to and influencing some aspect of health. These health-related components are comprised of muscular fitness, cardiorespiratory fitness, body composition and metabolism (Garber et al. 2011). The level of physical activity and physical fitness vary between individuals from low to high, each individual has some level of physical activity and fitness.

It has been argued that health and fitness related initiatives overemphasis the significance of moderate to vigorous activity and that people are misled into thinking that they can not be physically active without exercising (Hooper & Leoni, 1996). Current physical activity recommendations by most public health agencies focus on combinations of moderate-to-vigorous physical activities, i.e. on activities of 3-6 metabolic units (moderate level) and > 6 metabolic units, which are considered as vigorous physical activities. However, physical activity is a continuum from light activity and to vigorous physical activities and exercise is only one subset of physical activity. Physical activity is any musculoskeletal activity resulting in energy expenditure that is above resting levels, exercise being a subset of physical activity, *exercise* is often defined as *intentional physical activity* for improving health and fitness (Garber et al. 2011). Thus, even without engaging in exercise routine, an individual can be physically active. Time spent doing intentional exercise typically takes only small part of a day and there is considerable amount of time left for inactivity and non-exercise activities (Ekblom-Bak et al. 2014). *Non-exercise physical activity* is term used to describe activities that are embedded in the daily life and mainly performed with low intensity (Hamilton et al. 2007; Levine, 2002). Distinction between the two terms is important in understanding the physical activity continuum as the amount of light intensity activities that are executed during normal daily life can vary significantly (Hamilton et al, 2007).

Endurance training represents one extreme of physical activity. It commonly contains exercises at different intensity levels, from several minutes up to several hours ultimately increasing the capacity for prolonged repetitive, high-intensity, low resistance (Nader, 2006). Typical endurance training exercises are running, swimming and cycling. Endurance can be seen as an individual’s capability to perform repeated and uninterrupted skeletal muscle actions for extended periods below maximal speed or power output (Hawley 2009). *Strength training* represents the other extreme of physical activity, it is mode of exercise aiming at improving (maximum) strength of an individual. It involves muscles exerting force to external load while contracting repetitively usually at a workload above the aerobic capacity of a muscle. Strength training most commonly comprises high intensity, short lasting contraction that fatigue muscles. (Murton & Greenhaff, 2013.).

2.2 Health benefits and physiological adaptation induced by physical activity

Being physically active provides wide range of health benefits, including improvements in the functional ability and reducing the risk for variety of diseases (Powell et al. 2011). The physical activity induced reduced risk of all-cause is well established in scientific literature and numerous researches have assessed and demonstrated the health benefits and preventive role of physical activity on chronic diseases (Warburton et al. 2006; Reiner et al. 2013). Coronary heart disease was the first illness for which the occurrence was shown to be decreased by regular physical activity and studies have shown favourable long-term effect with people who were physically active having a lower risk of suffering from a coronary heart disease later in their life (Powell et al. 2011; Reiner et al. 2013). It is also suggested by studies that in the prevention of the development of the non-communicable diseases, which primarily result from unhealthy lifestyle and normally progress slowly over time, physical activity may be a crucial factor. Lower risks of developing a type 2 diabetes are also associated with higher rate of physical activity, together with physical fitness level and weight of an individual. (Reiner et al. 2013). Low cardiorespiratory fitness and muscle strength have also been associated with metabolic syndrome and it has been suggested that greater muscular strength is a primary preventer of the syndrome (Atlantis et al. 2009). The relationships between physical activity and the occurrence of dementia and Alzheimers have also been studied and it has been suggested that physical activity may help preserve cognitive function (Podewils et al. 2005; (Reiner et al. 2013).

Numerous randomized trials and meta-analyses on exercise training have contributed to the evidence of efficacy and effectiveness of exercise training in the improvement of physical fitness and biomarkers of many diseases (Walburton et al. 2006; Haskell et al. 2009). A question of whether it is the accumulation of physical activity in general or improving individual's fitness capacity that is more beneficial to health has been discussed in many studies. There is evidence that higher levels of VO_{2max} are connected with decreased risks of diseases and mortality. But it seems that people engaging in low intensity physical activities may not improve their fitness level whereas individuals doing regular higher intensity exercise generally have also better aerobic fitness capacity (higher VO_{2max}). (Swain, 2005.).

Regular physical activity stimulates health benefits, by means of acute and chronic physiological changes caused by it. There are multiple pathways through which the health benefits of physical activity are achieved, some of them unknown. In part, the benefits are mediated by physical activity (exercise) induced metabolic and molecular remodeling of skeletal muscle (Egan & Zierath, 2013). The voluntary movements activate bodily systems (neuromuscular, cardiovascular, and respiratory) differently based on speed, duration and resistance of the specific movement. Together with individual's physical fitness level they ultimately define the physiological effects of the specific activity (Hawley 2009). Therefore, the specific physiological changes depend on the type of activity performed, but also on volume, dose-response and intensity of the activity (Powell et al. 2011; Howley 2001).

2.2.1 Exercise-induced adaptation

Maintaining or improving aerobic fitness and muscular strength through exercise training have been shown to enhance metabolic dysfunction and prevent many chronic diseases. Each factor of physical fitness (muscular and cardiorespiratory fitness, body composition and metabolism) plausibly influence some aspect of health and, in general, higher level of cardiovascular and muscular fitness are associated with lower risk of inferior health. (Garber et al. 2011.) Exercise can cause extensive metabolic and molecular remodeling of skeletal muscles by which the health benefits are achieved by. The functional consequences of adaptation are controlled by training volume, intensity and frequency. (Egan & Zierath 2013.).

A physiological change requires a stimulus, in a case of exercise it is the repeated bouts of muscle action. Regular exercise fosters positive structural and metabolism adaptations in the contracting organ, in other words, in the skeletal muscle. Skeletal muscles are malleable and, over time, in response to this repeated contractile activity, muscle can show functional adaption. Although both endurance and strength training can individually stimulate health benefits and physiological changes, varying effects can be identified. Physiological adaptations are exercise specific to stimulus and the responses of aerobic and strength training are very different as they represent different ends of the exercise continuum and thus, they impose different demands on muscle contraction. Strength training exercise imposes a low-frequency, high resistance demand whereas aerobic exercise imposes a high-frequency (repetition) and low power output demand on muscle contraction. (Egan & Zierath 2013.). Long-term strength training elicits both neural and muscular adaptations that cause changes in muscle size, strength and power. Endurance training induces many metabolic and restructural changes, such as increase in mitochondrial density and enzyme activity, muscle fiber-type transformation and substrate metabolism, whereas strength training increases maximal contractile force output by altered neural recruitment patterns as response to overload and elicits synthesis of contractile proteins that are responsible for muscle hypertrophy (Coffey & Hawley, 2007). Table 1 summarizes adaptations of endurance and strength training (Egan & Zierath, 2013).

Table 1. Endurance and strength training induced physiological adaptations (Adapted from (Egan & Zierath, 2013).

	Endurance	Strength
Skeletal muscle and exercise performance		
Muscle hypertrophy	↔	↑↑↑
Muscle strength and power	↔↓	↑↑↑
Muscle fiber size	↔↑	↑↑↑
Neural adaptations	↔↑	↑↑↑
Anaerobic capacity	↑	↑↑
Myofibrillar protein synthesis	↔↑	↑↑↑
Mitocondrial protein synthesis	↑↑	↔↑
Lactate tolerance	↑↑	↔↑
Capillarisation	↑↑	↔
Mitochondial density and oxidative function	↑↑↑	↔↑
Endurance capacity	↑↑↑	↔↑
Whole body and metabolic health		
Bone mineral density	↑↑	↑↑
Inflammatory markers	↓↓	↓
Basal metabolic rate	↑	↑
Percent body fat	↓↓	↓
Lean body mass	↔	↑↑
Resting insulin levels	↓	↓
Insulin response to glucose challenge	↓↓	↓↓
Insulin sensitivity	↑↑	↑↑
Resting heart rate	↓↓	↔
Stroke volume, resting and maximal	↑↑	↔
Systolic blood pressure at rest	↔↓	↔
Diastolic blood pressure at rest	↔↓	↔↓
Cardiovascular risk profile	↓↓↓	↓
Flexibility	↑	↑
Posture	↔	↑
Ability in activities of daily living	↔↑	↑↑

↑ values increase; ↓ values decrease; ↔ values remain unchanged; ↑ or ↓ small effect; ↑↑ or ↓↓ medium effect; ↑↑↑ or ↓↓↓, large effect; ↔↑ or ↔↓, no change or slight change

2.2.2 Concurrent training

It has been argued that skeletal muscle demonstrates notable plasticity to different loading patterns and that muscle tissue can distinguish between specific signals imposed by physical activity of various duration, intensity and type. However, these unique and relatively distinct adaptations of different training modes may be comprised when combining strength and endurance training. Studies of concurrent strength and endurance training have reported interference effects in adaptation. Concurrent training has been shown to result in reductions of strength, power and hypertrophy (relative to strength training alone) and that there are high interindividual variations in the change of maximal voluntary contraction after concurrent training. (Wilson et al. 2012). Some individuals have been reported to experience strength gains while others experience strength decrements (Karavirta et al. 2011). It has been argued that especially when concurrent training increases the total training volume substantially (with possibility of overreaching) together with competing adaptations, it may be the specific components of endurance training that are responsible for the interference effects. (Wilson et al. 2012.)

Even though commonality between long duration endurance and strength training is low, commonalities of adaptation may be high and thus, not so competing, between short duration, high intensity sprinting and strength training. It has been found in a study by Balabinis et al (2003) that shorter duration high-intensity sprinting exercise did not result in strength or power reductions. From purely performance perspective, when comparing to single mode of training, it is likely that alternating strength and endurance modes during concurrent training reduces the specifically gained adaptations of muscle hypertrophy and (or) mitochondrial adaptation responses induced by training (Hawley 2002).

2.3 Quantity and quality of physical activity

Evidence-based recommendations for physical activity describe the needed volume of exercise to reach health benefits. The sum of physical activity that is accumulated within a certain time period, characteristically within a week, is defined as volume, and it is comprised of duration, frequency and intensity of the activity (Powell et al. 2011). With at least 150 minutes of moderate intensity activity most of the health benefits can be achieved, and both endurance and strength training are beneficial for health (Garber et al. 2011). However, it remains unclear what is the optimal or minimal volume of physical activity for health benefits and other physiological changes (Walburton et al. 2007). In general, higher amount of physical activity is associated with greater benefits (Garber et al. 2011).

Moderate to vigorous intensity physical activity is emphasized in most physical activity recommendations and there is strong scientific evidence that meeting the international physical activity recommendations, in terms of volume and intensity, can provide substantial health benefits. Based on large cohort studies it has been shown that energy expenditure of about 1000 kcal/week of moderate intensity activity is associated with lower risks of cardiovascular diseases and premature death. This amount equals to intensity of about 3-5.9 METs and 10 MET hours/week. These MET hours can also be achieved with less time by vigorous intensity activities. (Garber et al. 2011.) Common approach to achieve this volume of physical activity and associated health benefits is by applying combination of intensities of endurance and strength training. But it also seems that there is no lower threshold for health benefits. Even small increases in physical activity above the *baseline* seem to result in risk reductions, even if recommended levels are not met. It seems also that there is no upper level where health benefits start to lessen. Different types of physical activity promote different physiological responses and health outcomes and there seems to be a curvilinear reduction of risk of various diseases and conditions. (Powell et al. 2011.).

2.3.1 Exercise intensity

From sport science point of view, it has been recognized that mode of exercise together with frequency, duration and intensity are vital for the extent of physiological effects (Wisløff et al. 2009). It is still somewhat unclear whether high intensity activities, when controlling volume, can bring more health benefits than moderate intensity activities and what is the relationship to benefits between volume and intensity, particularly of low volume and low intensity activities (Powell et al. 2011; Foulds et al. 2014). Nevertheless, exercise intensity is a major determinant when assessing exercise induced physiological changes (Garber et al. 2011).

Same as physical activity in general, also exercise intensity is often conveyed in absolute terms as energy expenditure (often in METs or kilocalories), irrespective of individual's fitness level. It can also be expressed in relative terms, as a percentage of individual's VO_{2max}, HR_{max} or maximum strength (expressed as percentage of one repetition maximum, 1RM) or subjective effort. Many scientific studies have not collected or measured in detail the intensity (absolute or relative), duration and frequency of physical activity, but have used subjective assessment such as light, moderate, and heavy in determining the intensity. This makes comparison of results in exercise intervention studies difficult as it cannot be presumed that methods of determining intensity are necessarily comparable to each other (Garber et al. 2011; Powell et al. 2011). Commonly used absolute and relative methods for classifying intensity are summarized in table 2.

TABLE 2. Commonly used methods for classifying exercise intensity (in absolute and relative terms) for cardiorespiratory endurance and resistance exercise (adapted from Garber et al. 2011). $\%HR_{max}$: percent of maximal heart rate, $\%VO_2max$: percent of maximal oxygen uptake, RPE: ratings of perceived exertion (scale 6-20), % 1RM: percent of one-repetition maximal effort.

Cardiorespiratory Endurance Exercise					Resistance exercise
	Relative intensity			Absolute Intensity	Relative intensity
Intensity	**$\%HR_{max}$**	**$\%VO_{2max}$**	**Perceived Exertion (RPE)**	**METs**	**% 1RM**
Very light	<57	<37	<Very light (RPE < 9)	<2	<30
Light	57-63	37-45	Very light to fairly light (RPE 9-11)	2.0-2.9	30-49
Moderate	64-76	46-63	Fairly light to somewhat hard (RPE 12-13)	3.0-5.9	50-69
Vigorous	77-95	64-90	Somewhat hard to very hard (RPE 14-17)	6.0-8.7	70-84
Near-maximal to maximal	≥96	≥91	≥Very hard (RPE ≥ 18)	≥8.8	≥85

Muscular fitness is comprised of strength, power and endurance and each of these functional parameters improve as a result of appropriate training program (Garber et al. 2011). In general, individual’s physical fitness is improved more by high than low intensity physical activity. Strength training excites synthesis of contractile proteins that are primary reason for muscle hypertrophy and for increased maximal force production (Coffey & Hawley 2007).

The predominant opinion is that for skeletal muscle hypertrophic adaptations, an intensity greater than 60 % of 1RM is needed. It has been presumed that this intensity level is needed to recruit all types of muscle cells, particularly those associated with larger motor units. (Schoenfeld et al, 2014.).

Endurance training results in adaptations of the cardiorespiratory and neuromuscular systems. Enhanced endurance is associated with improved oxygen uptake and VO_{2max} is probably the single most important factor at maximal exercise. At low work intensities/rates at work, the demands on cardiovascular and respiratory systems are relatively small. But as the rate of muscle activity increases, these systems will ultimately meet their maximum capabilities. (Heldegrud et al. 2007). It has been shown that exercise below a minimum intensity threshold, of approximately below 45% of $VO_{(2R)}$ (percentage of difference between the maximum and resting VO_{2max}) for higher fit individuals and below 30% of $VO_{(2R)}$ for lower fit individuals, will not challenge enough to result in improved VO_{2max} or in other physiological parameters (Swain et al. 2002; Garber et al. 2011) and the improvements in VO_{2max} are intensity dependent (Helgerud et al. 2007). There is also growing evidence that higher intensity training (typically > 60 % aerobic capacity) will bring greater cardioprotective benefits than moderate intensity activities (Swain et al. 2006; Garber et al. 2011).

There are numerous factors that can influence how an individual responses to exercise. The fitness level of an individual can be seen as intermediate factor between physical activity and physiological changes. It is suggested by many studies that moderate exercise intensity is sufficient for women and older men to reduce the risk of cardiovascular disease, but some groups need more vigorous exercise for further benefits (Wisløff et al. 2009). In a review assessing the exercise intensity needed for athletes, it was concluded that well-trained athletes needed near maximal intensities to improve their aerobic fitness, while 70-80 % intensity provided a sufficient stimulus for moderate-trained athletes (Midgley et al. 2006). Also, the progressive overload principle of training is suggested to be applicable to exercise intensity. This means that a greater than normal stress or load on body is needed for training adaptation to happen. Once body has adapted to the specific stimulus, a different stimulus is needed for further change. For a muscle to increase strength, it needs to be gradually exposed to larger load than it is used to. In endurance training, muscles need to work longer or at higher intensity (McArdle et al. 2010, 453).

An exact threshold for health benefits or improving fitness may also depend, besides on the current fitness level of an individual, on the interaction of training volume, frequency and duration. Therefore, it is difficult to define an exact minimum intensity level needed for physiological changes. (Garber et al. 2011.)

2.4 Non-exercise physical activity and impact on health

Most public recommendations for physical activity call for moderate to vigorous intensity activities and therefore, the scientific research has been mostly focused on these parameters and been limited around others. However, more recent research has also shown that non-exercise type of physical activity is also important to health. The metabolic rate can be substantially increased even with minor physical activities (Levine 2002). A review from 2011 (Powell et al. 2011) concluded that any increase to the lowest levels of activity will start showing health benefits. The greatest functional and health benefits were found with increments in the lower end of physical activity spectrum with adults who were not reaching the recommended physical activity levels.

Characteristics of non-exercise physical activity are summarized in table 3. Typical non-exercise activities (that are often replaced by prolonged sitting) include daily activities such as household chores (cooking, cleaning, shopping) as well as higher intensity activities not typically classified as intentional exercise (e.g. vacuuming, moving, snow shoveling).

Table 3. Characteristics of non-exercise physical activity. Adopted from Hamilton et al, 2007.

Non-exercise physical activity	
Frequency	Up to thousands of bouts of non-exercise activity per day, 7 days per week
Intensity	Greatly variable, usually low (<3 METs)
Duration	Prolonged, highly variable, but usually more than 8h per day
Modality	Mainly involving movements while standing, leisure or non-leisure physical activity
Recommendations	Not usually included in the physical activity recommendations, mostly guidelines to limit sitting time. Specific interactions between frequency, intensity, duration and modality of non-exercise to replace inactivity time is largely unknown

It was found in a 12.5 year follow up study of 60-year old Swedish men and women that a relatively active daily life reduced the risk of a first-time cardiovascular disease event by 27 % and all-cause mortality by 30 % when compared to low activity, regardless of regular exercise habits. Also, the connection with metabolic syndrome was found to be significantly lower for subjects with higher levels of non-exercise physical activity in both non-exercising and regularly exercising groups. Further, the higher level of non-exercise physical activity was associated with more preferable profile for lipids in both sexes and for insulin and glucose in men. The study did not find associations between non-exercise physical activity and blood pressure, which may indicate that non-exercise PA has important metabolic effect, but higher intensity physical activity is needed for preferable changes in blood pressure. (Ekblom-Bak et al. 2014.) Findings from study of healthy Australian adults also suggest that there is favorable association with light intensity physical activity and blood glucose and effects of low intensity activity are independent from moderate-vigorous activity (Healy et al. 2008). Also, another more recent experimental study has indicated adverse metabolic health effects after reducing non-exercise physical activity in exercising and non-exercising young men and women (Stephens et al. 2011).

3 SEDENTARY BEHAVIOUR

Prolonged inactivity through sitting and other sedentary behavior comprises major part of individuals' daily life in the modern world. The society allows and enables the avoidance of physical activity and further technological advances are likely to even increase the inactive time during individuals' leisure and occupational time. The lack of physical activity or *inactivity* time has been defined as lacking muscle contraction by large muscle groups or as lack of whole-body movement. According to Booth et al (2014), from the health perspective, physical inactivity can be defined as "physical activity levels less than those required for optimal health and prevention of premature death". The generic term *sedentary behavior* is associated with low levels of metabolic expenditure and it classifies behaviors such as sitting and other activities that involve low metabolic expenditure (of 1.0 – 1.5 METs) as sedentary (Owen et al. 2014).

3.1 Accumulation and prevalence of sedentary life

The changes in the physical, social and economic environments are associated with significant reduction demands for physical activity. Several studies have been carried to measure (objectively or self-reported) the sedentary time throughout daily lives and the way the inactivity time is accumulated. In past, most of studies have focused on leisure time sedentary behavior but sedentary behavior can happen in different domains and contexts (Marshall et al. 2010). Sitting time is typically accumulated at work/school, during passive transportation or at leisure in the context of television watching, computer usage or at other leisure time activities (Marshall et al. 2010; Owen et al. 2014).

Objective measurements of daily physical activity have shown that people spent most of their days inactive; globally 23% of adult men and 32% of women have been reported to be insufficiently physically active (World Health Organization, 2018). A study of sedentary behavior of US adults revealed that participants spent 54.9 % of waking time in sedentary activities (Matthews et al. 2008) and similar behavior has been found in other countries. In UK people have been reported spending 68% of activity measurement time in sedentary activities on workdays and 60% on non-workdays (Clemes et al. 2014).

There are also differences reported in the time spent in sedentary behavior between age and gender groups. Matthews et al (2008) found that there are two peaks in sedentary activity time accumulation. Children age 6-11 years were least sedentary and adults over 70 years most sedentary, but the peaks where sedentary time increases about 2 h/day was found between ages 30 to 39 and ages 70 to 85 years. Females were found to be more sedentary throughout youth and early adulthood, but men more sedentary after age 60 years. (Matthews et al. 2008.) In most countries the current physical activity recommendations have almost no recommendations relating to sedentary activities even though there is growing amount of evidence of the deleterious association between inactivity behavior and poorer health outcomes. However, in recent years there has been an increased emphasis on how to reduce sitting time. For example, in Finland in 2013, reducing daily sitting time was added as a goal to health promotion campaign.

3.2 Inactive physiology and health consequences

Sedentary behavior is ubiquitous and spontaneous, thus making the understanding of its physiologic consequences challenging. It is known that the human body adapts to exercise but also reacts to inactivity. There is evidence that the physiology of inactivity is unique and has distinct biological processes operating that are separate from exercise physiology. (Lyden et al. 2014.) The health consequences of prolonged inactivity time and the detrimental association between total sedentary time and cardiometabolic biomarkers have been demonstrated by many epidemiological and physiological studies since 1950s. Overall the studies have provided evidence that reduced aerobic capacity and muscle strength, loss of muscle and metabolic function are consequences of prolonged sedentary behavior. These researches have mostly used protocols of bed rest in humans and immobilization of limbs in rodents and although they have given insight into the physiological impacts of extreme sedentariness, the applicability to more typical daily living has been somewhat uncertain. (Lyden et al. 2014; Thyfault et al. 2014.) But there is emerging evidence that the underlying physiology of prolonged sitting with loss of local contractile stimulation is related to inactivation of lipoprotein lipase and its deleterious impacts on lipid metabolism (Owen et al. 2010; Hamilton et al. 2003). A study with Australian cohort showed deleterious associations between sitting time and metabolic measures (waist circumstance, BMI, systolic blood pressure, lipids and glucose and insulin profiles) (Healy et al, 2008) and a recent research by Duvivier et al (2013) suggests that unfavorable changes in circulating lipids and insulin sensitivity are connected to prolonged inactivity time, such as sitting time. As skeletal muscle has important role in clearance of triglycerides and glucose from plasma, a probable mechanism of these unfavorable metabolic changes is the lack of muscle contractions. In other words, fewer skeletal muscle contractions due to sedentary time may result in insulin resistance and possibly in lipid abnormalities (Healy et al. 2008). Research has also indicated that standing, as it engages large muscles of lower body, may not have the same negative metabolic effects as sitting, enticing EMG and skeletal muscle lipoprotein lipase changes, although it is also of lower energy expenditure activity (Owen et al. 2012).

Studies have also investigated the dynamics accounting for weakened insulin action in relation to periods of low muscle activity. A study by Stephens et al (2011) examined specific metabolic effects of minimizing low-intensity muscle activity, as separate from exercise insufficiency. They found that 1 day of reduced non-exercise time reduced whole body insulin action and together with reduced energy intake the decline in insulin action was significantly lessened, but not totally prevented. Further, several epidemiological studies have reported that time spent in tasks that require little muscle activity is inversely related to insulin action. For example, a study of healthy Australian adults who meet the recommended amount of physical activity, showed that television watching time was positively associated with many metabolic risk variables (Healy et al. 2008).

Although the total sedentary time is associated with the mentioned health deteriorating factors, also the way it is accumulated seems to be important. It has been uncertain to some degree whether the unfavorable health effects are due to too much sitting or too little light, moderate and/or vigorous activity or combination of these. But there is increasing amount of evidence to suggest that sedentary behavior is a distinct health risk and independent from lack physical activity. (Owen et al. 2010). Even for adults who meet the recommended 30 minute of moderate intensity activity for most days, there are detrimental metabolic consequences of the 9-10h of sitting time (Healy et al. 2011). Although several studies indicate that metabolic consequences of sedentary behavior can be improved by moderate to vigorous physical activity, it has also been argued that one hour of daily physical exercise does not counteract the undesirable metabolic effects of prolonged sitting (Duvivier et al. 2013). Therefore, it is not enough to consider whether an individual involves him or herself in sufficient physical activity to achieve health benefits, but also the amount of time that an individual spends in sedentary behaviors should be considered. Even for individuals that meet the physical activity guideline recommendations, there can be deleterious metabolic consequences because of the way the non-exercise time is occupied. Excessive sitting on daily basis and prolonged sitting periods lasting for hours have been reported to trigger significant health risks and there is a 5% increase in the risk of death with every additional hour of sitting for individuals that sit more than 7 hours per day (UKK Institute, 2015).

Typically, even the most sedentary, but otherwise healthy, individuals have breaks from inactivity to perform activities of daily living (Lyden et al. 2014). There are many factors, including occupational and leisure-time factors, and individual differences that effect the way the sedentary time is accumulated. It has been reported that, regardless of total sedentary time and moderate to vigorous exercise time, more interruptions in prolonged sedentary time are beneficially associated with metabolic risk factors (Healy et al. 2008).

A study using data from a National Health and Nutrition Examination Survey assessed selected biological and health markers (body mass index (BMI; kg/m^2), waist circumference, C-reactive protein, HDL-cholesterol, fasting LDL-cholesterol, total cholesterol, fasting triglycerides, fasting glucose, fasting insulin, white blood cells, neutrophils, and homocysteine) known to be associated with physical activity. Those individuals engaged with minimum or more than recommended MVPA, regardless of light physical activity and sedentary balance, had more favourable biological markers than those with less than recommended amount of MVPA. There was also some suggestive evidence that individuals whose light-intensity physical activity exceeded their sedentary time had improved health markers, even if they engaged in less than recommended amount of MVPA. (Loprinzi, 2014.) Another pilot study examining the changes in health markers provided preliminary evidence that the combination of exercise and reduction of sedentary time can potentially result in enhancements in metabolic markers that are not visible with exercise alone (Kozey Keadle et al. 2014). Characteristics of inactivity physiology are summarized in table 4.

Table 4. Characteristics of inactivity physiology. Adapted from Hamilton et al, 2007.

Inactivity physiology	
Inactivity physiology defined	Acute and chronic physiological effects of sedentary behaviours (non-exercise activity deficiency)
Modality	Emphasis on sedentary behaviours (sitting mostly) while not standing
Reference comparison	Non-exercise physical activity
Energy consumption	Activity related energy expenditure is low during sitting (compared to even light intensity movements while standing)
Potential outcomes of sustained sitting	Cardiovascular disease, higher mortality, metabolic syndrome, plus many others
Cellular mechanisms	Partially still unstudied, potentially distinct from exercise

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4 DAILY PHYSICAL ACTIVITY

Skeletal muscles contract to generate force and to produce and absorb work necessary in everyday life. Physical activity consists functional entities of single movements which are characteristic to the type of activity (sitting, running, weight lifting etc.). The speed, resistance and duration of the specific movement together with intensity of the activity determine the total amount of physical activity and energy expenditure, which is also influence by individual's body mass. Physical activity and sedentary behavior are undertaken in different contexts or domains. In broader sense, physical activity includes exercise and physical activities done as part of daily habitual life, during work, leisure and active transportation. (Garber et al. 2011.) Similarly, sedentary behavior happens in these same contexts.

4.1 Daily energy expenditure

The daily *energy expenditure* is typically divided into three components: resting energy expenditure (REE), thermic effect of food (TEF) and activity induced energy expenditure (AEE), often called activity thermogenesis. Resting energy expenditure is defined as the metabolic rate of an individual to maintain vital functions. In sedentary individuals, the REE accounts for about 60% of daily energy expenditure. Thermic food effect is the energy expenditure related to food consumption, absorption and digestion and it accounts for approximately 10-15% of daily EE. (Westerterp, 2008.). The activity thermogenesis can be further separated in to two components. Non-exercise activity thermogenesis (NEAT) is comprised of low energy expenditure of non-exercise activities which are not considered intended physical activity, such as exercise, and it includes sedentary activities associated with little energy expenditure, but also activities at low intensities. The other component of activity thermogenesis is the exercise-related activity thermogenesis. (Levine, 2002.).

Even though there are many modalities of non-exercise activities, the frequency and collective duration of the activities during the day is very high. It has been estimated that exercise accounts for only about 3-5% of total weekly hours and sleep about 30%. This leaves 65% of weekly hours available for non-exercise activities. Exercise does contribute to the total energy expenditure, but even with regular exercisers the non-exercise activities constitute the majority of weekly energy expenditure (figure 1). In other words, the total amount of time and energy expenditure of exercise is less than that of cumulated by non-exercise physical activity. (Hamilton et al. 2007.).

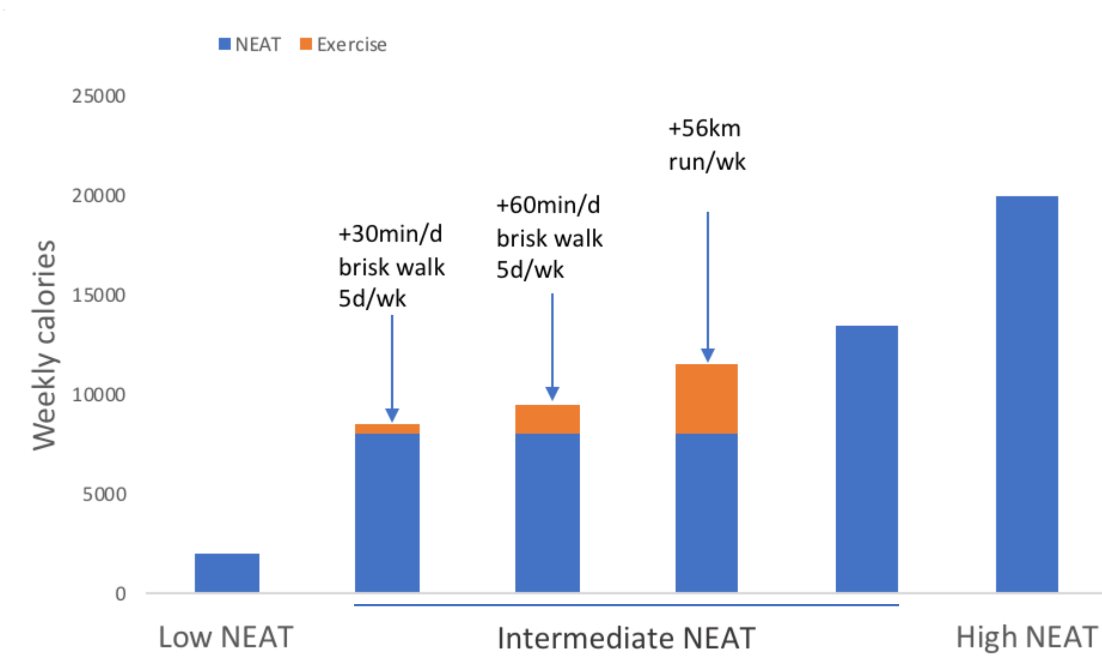


Figure 1. Variability of energy expenditure with different NEAT (Adapted from Hamilton et al. 2007).

For the majority of people in developed countries, the exercise-related thermogenesis is insignificant or zero. In general, the activity thermogenesis can vary considerably between individuals, total energy expenditure ranging from about 15% in very inactive individuals to about 50% or more in physically highly active people. (Lam & Ravussin, 2016; Levine, 2002.) However, it has been shown that changing the postural position from sitting to standing or participating in light physical activity significantly increases energy expenditure (Levine et al. 2005). Individuals typically have sporadic bouts of non-exercise activities during waking hours, resulting in thousands of muscle contractions that can require greater energy expenditure than single continuous exercise bout. (Hamilton et al. 2007.) Also, the time spent in sedentary activities is significant because it contributes to a reduction of overall energy expenditure and replaces other intensity physical activity. It has been estimated that replacing two hours of light physical activity (2.5 METs) by sedentary behavior (1.5 METs) can reduce energy expenditure by about 2 MET-hours/day, energy expenditure approximately equal to 30 min of walking. (Owen et al. 2010.).

4.2 Physical activity patterns

In a study by Scheers et al (2012), describing activity patterns among normal-weight (together with overweight and obese) adults in Belgium, it was found that most time was spent in sedentary activities (about 70% of the day) and least with vigorous activities (0-1% of the day). Men had, on average, about 16 bouts of physical activity lasting at least 10 minutes, women on average less than 11 bouts. The average duration of sedentary bout was over 13 minutes. Mean hours of sedentary behaviour differed between weekdays and weekend, being highest on Sunday and lowest on Saturday. Similar activity pattern could be seen with moderate to vigorous activities, most activity accumulated during Saturdays, least on Sundays. (Scheers et al. 2012). Table 5 presents the indicators of physical activity in the study.

Table 5. Indicators of physical activity and sedentary behaviour (adapted from Scheers et al. 2012).

Activity pattern	**Men**	**Women**
Sedentary behavior (<1,8MET), hours/day	16.8±1,9	16.5±1.6
Light PA (1,8-3MET) hours/day	3.4±1.0	4.5±1.2
Moderate PA (3-<6MET) hours/day	3.5±1.6	2.8±1.2
Vigorous PA (>6MET) hours/day	0.3±0.3	0.2±0.2
Accumulated 10min bouts (hours/day)	2.7±1.5	1.8±1.2
Number of 10 min bouts (n/day)	16.5±9.4	10.9±7.5
Average duration of sedentary bout (min/bout)	13.6±4.5	13.1±3.0
Number of breaks in sedentary behaviour (n/day)	77.8±15.2	77.1±12.2

A study measuring desk-based sitting in the occupational context showed that full-time office employees spent on average 8.7±0.8 hours/day at work, of which 67% was spent sitting at the desk (5.8±1.2 h/d) and another 4% in other workplace settings. On average employees were reported to change postural position from sitting 3 times/hour (29±13/day). (Ryde et al. 2014).

An Australian study investigated domain-specific sitting times and health outcomes and the differences between weekdays and weekends. On weekdays both men and women reported more sitting time at work than in other domain, men sitting 50% more than women. Median sitting times for watching television were same for both sexes, 2 hours on weekdays and 3 hours on weekend. 1 hour on weekdays and 2 hours on weekends were reported for both travel and other leisure activities. (Marshall et al. 2010.) Recent studies have also shown, for example, that there is no difference in daily sitting time between women with sufficient (>30 min/day) or insufficient levels (<30 min/day) of moderate to vigorous physical activity (Craft et al. 2012). Therefore, it has been concluded that sedentary behavior is independent of time spent in other intensity physical activity (Thyfault et al. 2014).

4.3 Individual physical activity patterns

An individual's physical activity level (PAL) is determined by the distribution of time spent in different intensity physical activities. There has been discussion whether it is possible for an individual to score high in one of the physical activity dimensions (ie. recommended exercise) while scoring low in another (ie. high sedentary time) and it remains somewhat unclear whether, and how much, engaging in high-intensity physical activities actually contribute to the physical activity level. According to some studies, high intensity activity does not influence the activity level much as the portion and duration of high intensity exercise for normal population is small. It has been argued that the impact of vigorous activity on PAL may even be compensated by reducing energy expendituroutside the training sessions, particularly in the case of obese and elderly individuals (Westerterp, 2008). A recent study on physical activity profiles by Thompson and Batterham (2013) confirm that the nature of physical activity is highly heterogeneous and multi-dimensional. Some participants achieved a very high physical activity energy expenditure values (high PAL) through considerable activity below 3 METs, assumingly through NEAT. Other individuals participated in substantial amount of vigorous intensity physical activity, while at the same time had relatively low overall physical activity energy expenditure. Figure 2 illustrates five different participant profiles. (Thompson & Batterham, 2013.)

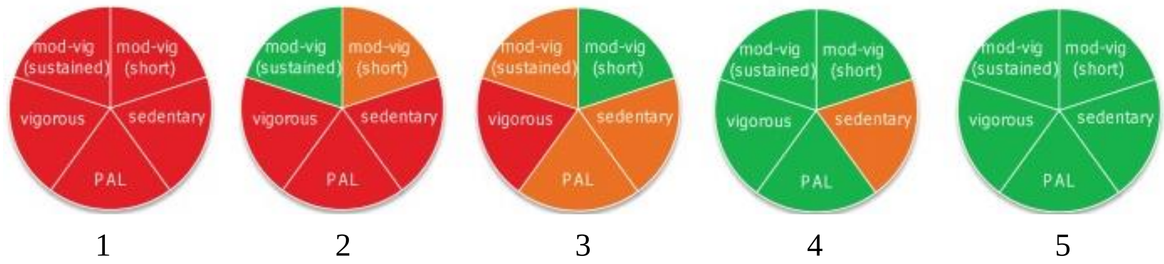


Figure 2. Individual differences in activity profiles. Adopted from Thompson and Batterham. 2013

4.4 Participation in exercise

It has been suggested that participation in intentional exercise aiming at improving physical fitness is independent of sedentary behavior and that sedentary behavior is not same as exercising too little. As mentioned, it has been estimated that exercise accounts for only about 3-5% of total weekly hours for average healthy individuals (Hamilton et al. 2007). Figure 3 shows the time spent sitting, standing, incidental stepping and purposeful exercise for people with different exercise levels in an Australian study (Craft et al. 2012). Study provided objective evidence that involvement in continued exercise is unrelated to daily sitting time in relatively healthy individuals meeting the physical activity guidelines. Even though participants spent an average of 146 min / week in moderate to vigorous activities, they still spent the majority (~62%) of waking hours sitting (Craft et al. 2012). There is also evidence that muscular inactivity during daily life is not decreased as a result of participating in sustained exercise nor does is increase the time spent in moderate and high intensities (Finni et al. 2014).

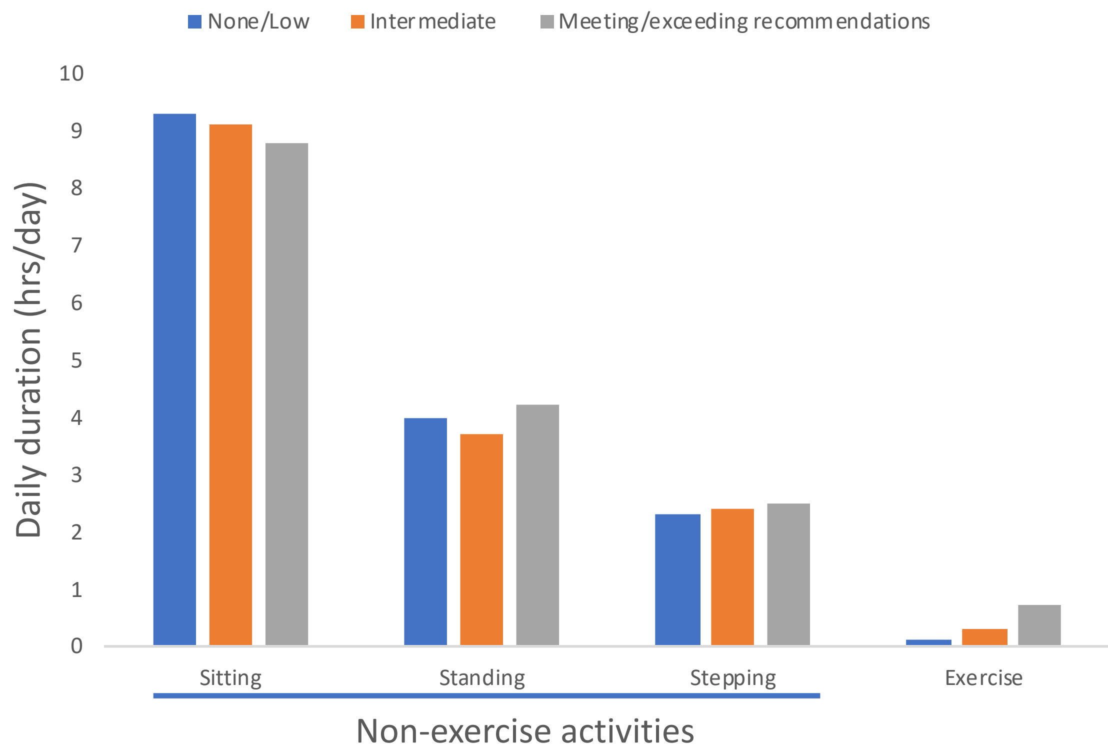


Figure 3. Time spent in sitting, standing, incidental stepping and purposeful exercise for individuals with different activity levels. Adopted from Craft et al, 2012.

Some studies have concluded that individuals participating in vigorous physical activity may compensate intensive exercise time with increased sedentary time (Wasenius, 2014). It has been suggested that, during an exercise intervention program, an increase in the exercise intensity may dispose individuals to compensatory decline in non-exercise physical activity. The increased physical demand of exercise may induce increased physiological fatigue with a proportional increase in recovery time. This in turn may lead to decreased non-exercise activity. If there is a decrease in the non-exercise physical activity, an increase in the sedentary time follows. (Ekblom-Bak et al. 2014). In a study determining if the daily physical activity energy expenditure is influenced by participation in single moderate or vigorous intensity exercise sessions in overweight or obese women, it was also found that for women performing vigorous intensity exercise, the daily energy expenditure was lower on the days of exercise than on days without exercise. Thus, women were found to spend more energy on physical activities beyond structured exercise on the days they did not participate on prescribed exercise, especially if the exercise was of higher intensity. (Wang & Nicklas, 2011.)

However, no clear consensus exists on whether or not individuals taking part in regular exercise compensate with a reduction in physical activity outside the training session. Participation in sustained exercise training was found not to have a compensatory reduction of non-exercise physical activity in a study by Rangan et al (2011). The results were the same for strength and endurance training, and when both exercise modalities were combined (Rangan et al. 2011). Also, Washburn et al (2014) found only minimal support for the hypothesis that exercise training results in reduced non-exercise physical activity and/or energy expenditure in healthy adults.

4.4.1 Muscle activity during physical activity/exercise

During physical activity skeletal muscles go through shortening and lengthening cycles and for some portion of this cycle muscle may contract isometrically. Muscle contraction can be maximal or submaximal and the number of involved motor units varies depending on the exerted force. Duty cycle is the percentage of one period during which a signal is active, the part of time that a muscle is activated during movement. Each muscle is activated at appropriate times for definite time and the activity is interspersed with periods of rest. The duty cycle usually increases with intensity because the activation period decreases less than the rest period. An increase in the duty cycle can be seen, for example, when increasing repetitive action such as walking. (Feher 2016, 335). The force generated by a muscle is proportional to the duty cycle time. When the cycle time decreases, so does the force development also.

In a study to quantify the daily activity and inactivity within Finnish population, the muscular activity of thigh muscles was measured. The thigh muscles were found to be inactive over 65% of the measurement time during normal daily life and longest inactivity period lasted approximately for 14 minutes (ranging 2.5-38.3 min). Also, high interindividual variability in the total inactivity times was also reported. The measured inactivity times ranged from 40 to 91% of total time. Time spent in light activities also had much between subject variability (3-45% of total time), but less variability was found in time spent on moderate or vigorous activities, 2-21% and 1-23% respectively. Based on this, it was indicated that differences between individuals in the light physical activity have a bigger impact on the inactivity time than moderate to vigorous physical activity. The same study found that the thigh muscle activity of standing still was 2.5 times higher than that of sitting down and walking slow causes 3 times higher muscle activity than standing. It was also reported that of muscle's maximum voluntary strength capacity only a fraction is used during normal daily life. (Tikkanen et al. 2013.).

In an exercise, there can be activity of a small muscle group involved (such in elbow flexion) or activity can involve large muscle groups, such as leg in running. If an individual engages in endurance or strength training with the same muscle groups, the respective activities can be said to be located at opposite ends of power continuum. In both exercise types the opposite forces (*resistance*) can be seen as the limiting factor for the number of repetitions before exhaustion. For strength exercise it is typically 1-10 repetitions, whereas for aerobic (endurance) exercise resistance needs to permit 200 or more repetitions.

An individual's ability react to different exercise intensities is an interplay between aerobic and anaerobic systems. At low intensities the aerobic system is dominant, with increased intensity (and energy demand) there is greater reliance of both aerobic and anaerobic systems. At the initiation muscle contract and at very high intense contraction rates the anaerobic system has dominant role. (Riddell et al. 2015.).

High intensity (interval) training (HIT) involves short sprints (less than 45 s) to long (up to 2-4mins) bouts of high intensity exercise with active or passive recovery periods in between. It is commonly considered to be one of the most efficient ways of improving physical performance as well as cardiorespiratory and metabolic function (McInnis & Gibala, 2017).

Evidence suggests that HIT can be considered as an effective alternative to lower-intensity endurance training (when energy expenditure is equivalent) and physiological adaptations occurring both in healthy individuals and diseased population can be similar or even greater (McInnis & Gibala, 2017; Wisloff et al. 2007). It has been suggested that those HIT protocols that require very high or even maximum oxygen uptake may provide the most effective stimulus for improving VO_{2max}. Training at these intensities naturally leads to high engagement of the neuromuscular/musculoskeletal system. It is argued that only exercise at these high intensities allow the recruitment of large motor units and realization of near maximal cardiac output which are needed for cardiovascular and peripheral adaptations. (Bucheit & Laursen, 2013.). SIT, sprint interval training, is similar to HIT exercise with constant load efforts near maximum intensity levels or at supramaximal levels (McInnis & Gibala, 2017).

The influencing factors in the chosen HIT protocol include the intensity and duration of work and the rest intervals. The number of intervals and series, the in-between rest periods and the intensity at which the session is carried out determines the total work performed. The varying length efforts, including rest periods, combine in a HIT session up to 40 mins. Although there are no studies comparing the neuromuscular effects of short and long bout HIT sessions, it has been suggested that short intervals may present a greater acute neuromuscular load. This is due to the fact that the intensity is usually higher with shorter intervals than longer; during longer intervals the majority of muscle fibers may be recruited, but the firing rate and the relative force development is likely to be greater during short intervals. (Bucheit & Laursen, 2013.).

Strength training most commonly comprises high intensity, short lasting contraction that fatigue muscles. (Murton & Greenhaff, 2013.) In a strength training aiming at increasing maximum strength, it is typical that for a single exercise the activity duration is about one to three minutes. A session can have varying number of sets, usually 3-4 sets with resting periods in between, that are performed with <6 repetitions (McArdle et al. 2010, 513). Intensity level is typically between 70–85% of one repetition maximum (1RM). The maximum strength is commonly quantified as greatest force that a muscle, or muscle group, can exert in an isometric contraction or a maximum load that can be lifted once. The force that a muscle exerts depends on how many motor units are activated and at firing rate. (Enoka 2008. 223). Muscle activation can be increased by recruiting more motor units, increasing the firing rate or by changing pattern of motor unit activation (Kamen 2005). Studies in the field have shown that the majority of adaptations needed for increasing the maximum strength involve loads lower than 90% of 1RM and time exposure to loads over that should be very short (McArdle 2010, 520). It has been suggested that high intensity exercise programs having low volume and long rest periods will mostly target muscle strength improvements (Ratamess et al. 2009; Mangine et al. 2015). Typical HIT and SIT and strength training exercises in terms of intensity are illustrated in figure 4.

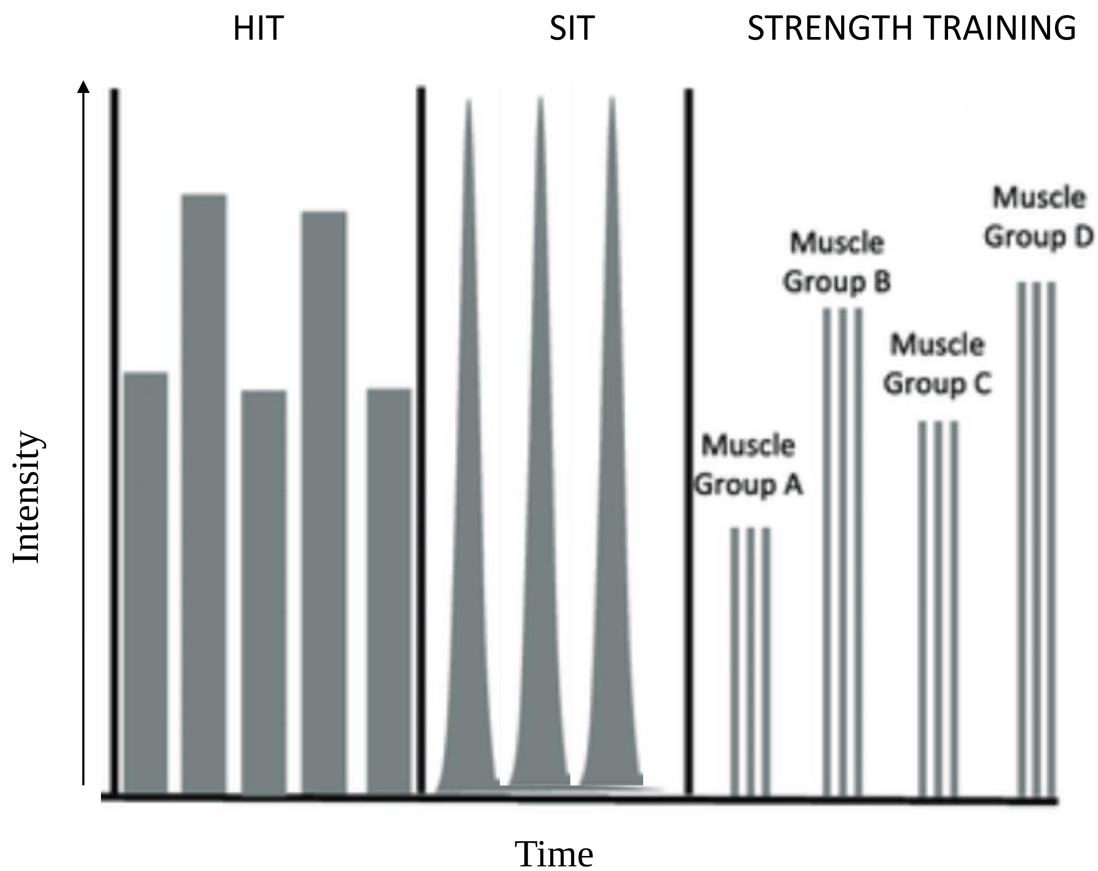


Figure 2. Graphical depiction of typical high intensity interval exercise (HIT) and sprint interval training (SIT) and strength exercises. Adapted from Riddell et al, 2015.

5 THE PURPOSE OF THE STUDY

The purpose of this study was to examine, through objective measurement of muscle activity, how intensive strength and interval running training sessions affect the overall daily physical activity patterns and what is the actual effectiveness of a training session, when considering muscle activity intensity, compared to same length period on a rest day. Further, the study aimed at finding out what is the intensity of muscle activity during an individual's single strength and interval running training sessions and whether the intensity (of muscle activity) correlates to specific physiological changes occurring over 10-week training period.

The research problem can be expressed through following research questions:

1. Are muscle activity patterns distributed differently during strength and interval running training session, and when compared to a period of equal length during a resting day? Specifically, how much moderate and high PA is contained in strength and interval running exercise sessions?
2. Do muscle activity patterns during a resting day differ from a day with structured strength or interval running exercise?
3. Are muscle activity patterns during a training session (and whole day) related with physiological changes (3000 m running time and strength improvements) during a 10-week intervention of combined strength and interval running training?

Hypothesis 1: Muscle activity patters differ significantly between strength and interval running training sessions and when compared to a period of equal length of REST (day without structured exercise) day. There is *more* time spent at higher muscular intensity level during RUN (interval running) training compared to STR (strength) training, but more near maximum strength levels are reached during strength training session. During comparable resting period, less MVPA is contained and overall lower muscle intensities are reached (Knuttgen, 2007).

Hypothesis 2: Moderate to vigorous physical activity does not increase time spent in sedentary activities as they are independent activity patters (Craft et al. 2012). There is no difference in the non-exercise time with days between days with exercise and the resting day (Finni et al. 2014).

Hypothesis 3: There is association with training at higher muscular intensity levels and/or having lower sedentary time with the improvements in maximum strength and/or 3000 m running time (MacInnis & Gibala, 2017).

6 MATERIALS AND METHODS

This study was part of a project “Strength and Endurance” that investigated the effects of intensive 10-week combined interval running and strength training. There were 45 healthy volunteers in the project who were recruited by advertisements in the local newspaper and online. Inclusion criteria were age range of 18 to 40 years, healthy and physically active men and women. Exclusion criteria were BMI > 30kg/m^2, any illnesses, musculoskeletal or cardiac problems, or medications that would prevent a subject to perform resistance and endurance training and testing. All subjects were active in some recreational sports and some had been training on a regular basis prior to the start of the exercise program.

The present sub-study used textile EMG electrodes embedded into shorts that enable measuring muscle activity in the quadriceps and hamstring muscles and assessment of muscle activity and inactivity parameters. The main project started in summer 2014 with control and pre-measurements, but this part of the study was carried out during the subjects’ 10-week intensive training period in fall 2014. Project’s post measurements were carried out in December 2014. I was responsible for all the data collection and data extraction. The results of this study have already been published in peer-review journal (Finni et al, 2016). For this thesis I have performed all the data analysis by myself.

6.1 Subject information

Subjects for this part of the study were recruited from the project subjects. Total of 25 volunteers signed in for the study, out of which 19 subjects were measured. Six subjects dropped out after the protocol was explained in detail, due to scheduling/personal reasons. Sufficient data with adequate quality was obtained from 10 subjects (5 women, 5 men) who fulfilled the criteria of having completed three measurement days (rest, interval running and strength training day). Subjects were aged between 22 and 37 years (29±5 years, height 173.2±8.8 cm and body mass 71.0±12.0 kg). 9 subjects were not included in the analysis due to missing at least one recording day with sufficient data (scheduling difficulties N=6, recording period too short N=3). The study was approved by the University of Jyväskylä ethics committee and the subjects signed an informed consent prior to any measurements.

6.2 Intervention

The exercise intervention program consisted of combined strength and interval running training (2 of each per week) for 10 weeks with intensity progressing week by week. The training program was planned according to current physical activity recommendations aiming at improving performance level (Heldegrud et al. 2007). Training took place either in the morning (between 7 and 9 am) or afternoon (between 4 and 7 pm) during working days based on participants' preferences and on Saturday mornings between 10-12 am.

6.2.1 Strength training program

The strength training program was designed to increase maximum and explosive strength, primarily targeting leg muscles, but also including exercises for the upper extremities and core muscles. Exercises for the lower extremities included half-squat, squat-jump, leg-press, knee flexion, calf-raises, and calf-jumps as well plyometric jumps. The primary exercise for the upper extremities was the bench-press. It is known that maximal and explosive training can increase muscle strength and induce positive changes in body composition and metabolism (Taipale et al. 2013). Subjects were free to include more exercises for upper extremities and core muscles. All exercises were performed with as much weight as possible and as strength increased, more weight was added to maintain near maximum resistance.

6.2.2 Interval running training program

The endurance part of the program consisted of 2 different interval running training routines, both done once a week. Routine A consisted of four 4-minute running sessions at a work rate that approached 60% of the subject's individual maximum heart rate (first weeks of training) progressing to 90% of individual maximum heart rate (last weeks). The intervals were separated by 4 minutes of active rest (walking or jogging at lower hearth rate). Routine B consisted of 3 rounds of 100 meters sprints repeated 3 times to include more neural stimulus. Between 3 sprints there was a 2-minute active rest period and between rounds there was a 5-minute active rest period. The 4x4 min intervals have been considered as effective as multiple high-intensity sprints in increasing aerobic capacity and when performed twice a week, these intervals have been shown to increase endurance (Heldegrud et al. 2007). Both routines started with 5-min warm-up and ended with 5-min active cool down period.

6.3 Study protocol

Prior to participating in the overall project, subjects' resting electrocardiography and health questionnaires were screened by a medical doctor. As part of the overall project, in the laboratory setting, pre and post 10-week training intervention, repeated measurements for body mass and composition, VO_{2max} and maximum isometric strength were performed for each subject and those results from pre-measurements were used as baseline fitness level in this study.

The study protocol for daily muscle EMG activity included measurements in the laboratory and day-long measurements of daily physical activity in the normal living environment during normal daily life. Measurements were done during three different days: a day including interval running training session (RUN), a day with strength training (STR) and a rest day (REST). Each subject was measured for these 3 days in random order depending on availability of the subjects for the EMG-measurements and also depending on the availability of the equipment, which were limited to two simultaneous measurements. For some of the subjects, the measurements were completed during 3 consecutive days, overall the measurements for STR and RUN were completed within two weeks (mean 3.7 days in between) and REST not more than four weeks away from STR or RUN. For part of the subjects one or more measuring days were repeated because of poor quality data or technical problems. The EMG recordings began between 7 and 9 a.m. so that the starting time within each individual was as consistent as possible during the three measurement days. The first two weeks of intervention was allowed for familiarization after which the daily measurements began.

Shorts, embedded with textile EMG electrodes, measuring muscle activity from left and right quadriceps and hamstring muscle groups (Mbody, Myontec Ltd. Kuopio, Finland) were put on in first measurement day at the laboratory. Short were selected so that they fitted tightly to the subject so that good skin contact for the entire day could be ensured. Conductivity enhancing gel (Redux Electrolyte Créme, Parker Laboratories Inc., Fairfield NJ, USA) was applied onto the textile electrodes that provide measure of muscle activity of the main locomotor muscles. The EMG signal from the four muscle groups was stored into a waistline module. The raw EMG signal, which was recorded with 1000 Hz sampling rate, was band ass filtered with 50 Hz-200 Hz (-3 dB), rectified and averaged over 100 ms nonoverlapping periods before storing into the module.

For each of the day long EMG measurements, subjects performed the following tasks in the morning of measurement days: 2 minutes of sitting and standing quietly and 1 minute of walking. For validation reasons, part of the subjects repeated this also in the evening before finishing the measurement for the day. In addition, for each measurement day, maximal isometric voluntary contractions (MVC) of knee extensors and flexors with a knee joint ankle of 107 degrees (David 200, David Health Solutions, Helsinki, Finland) were measured and best result of 3 trials was taken to represent MVC and further analyzed. In case that 3rd attempt increased more than 5% compared to previous attempt, a 4th attempt was made to get the best possible result.

On the first measurement day each subject came to the laboratory in the morning and the EMG recording device (shorts) were put on and set to record. In some occasions for the 2nd and 3rd measurement days, subjects could begin the EMG recording independently at home. After this the sitting, standing and walking tasks were performed after which subjects left for their normal living environment with instructions to live the day as they normally would. The subjects were informed to remove the EMG shorts when taking a shower and marking other interruptions (such as removing shorts for toilet visit) by pressing a button on the device. At individual subject level, the MVC measurements were performed always either in the morning or in the evening, mainly depending on their training preferences. If subject mainly trained in the mornings, then MVC measurements were done after morning training session and in the morning of rest day, for evening trainers in the evening. The daily measurements ended in the evening at the laboratory (for those subjects with evening MVC measurements) or at subject's home before bedtime. Subject filled in a daily activity dairy where they marked down exercise related activities (such as bicycling to work or taking a longer walk) for each day.

6.4 EMG analysis

Each EMG data recording was first visually assessed and corrected for artifacts with established procedures (Tikkanen et al. 2013). With help of data markers, the times that the shorts were removed for any reason resulting in artifacts were removed. Brief non-physiological signals (signal chancing more that 150-350 microvolts between two data points) observed in the data were replaced with median value from 10 earlier and following artifact with help of data filtering script. The actual filtering level (for removing the non-physiological signals) was determined at individual level and training sessions were filtered separately from rest of the day making it possible to use different filtering levels.

6.4.1 Data normalization and threshold determination

An average from one second period in the middle of the MVC where the signal was most consistent during the isometric contraction (that had resulted in maximum force) on the measurement day was taken as maximal EMG values (EMG_{MVC}). The EMG signal from each of the four muscle groups was normalized to the corresponding EMG_{MVC} value and reported as percentage of EMG_{MVC}. The normalization was done for each day separately. After normalizing each of the four channels they were averaged to mean thigh muscle EMG. Therefore, the results reflect the overall inactivity and activity periods of thigh muscle and are not specific to a single muscle. After this the EMG data was corrected for baseline drift by using a moving filter on a 5-minute window with a custom made Matlab algorithm (The MatWorks Inc, version 7.11.0.587) (Pesola et al. 2015).

From the tasks performed each morning/evening, the average EMG values for sitting, standing and walking were analyzed from the consistent signal (up to 2mins). The categorization into different physical activity groups was based on individually obtained EMG values. Muscle inactivity was determined as EMG amplitude below 3 mV and amplitudes between 3 mV and the mean EMG value during normal walking were classified as light activity. The amplitudes between mean EMG during walking and 2 times mean EMG during walking were considered as moderate activity, and amplitudes above 2 times mean EMG during walking were classified as vigorous activity (Tikkanen et al. 2013; Pesola et al. 2015).

The time spent at different activity levels (inactivity, light activity, moderate activity and high activity) were calculated using custom made Matlab script and reported as % of total time. The data was analyzed for the 50min time frame representing RUN, STR and REST periods and separately for the full recording time (9.1±1.4 h). REST period was taken from a day without planned training session during the same time of day that the given subject usually did training. The EMG variables that were calculated were inactivity time, light activity time, moderate activity time and high activity time. The distribution of EMG amplitude was further investigated by analyzing the proportion of different amplitude levels (0-1%, 1-2%, 2-3%, 3-4%, 4-5%, 5-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-60%, 60-70%, 70-80%, 80%-90% and 90-100% of EMG_{MVC}) and the difference between the three sessions and days were calculated.

6.5 Statistical analyses

Statistical analysis was conducted with SPSS version 22.0 (SPSS, Inc. Chicago, IL). Results are reported as means and standard deviations. The level of significance was set to $p < 0.05$. Shapiro-Wilk was used to test the normality of the data. Repeated measures analysis of variances (Anova) was used to test changes in the activity patterns. Friedman's test was used to test the difference in variables between STR, RUN and REST during 50 min period and whole day. Further, Pearson product-moment correlation coefficient was used to measure the association and effects of physical activity and physiological adaptation during the 50 min period and whole day. And the effects of the 10-week training intervention on physical adaptation (strength and endurance capacity) were tested using paired t-test.

7 RESULTS

The recordings were done approximately at the same time for each of the three days and the recording times for each of the three days were not significantly different (for STR 9.4±1.0 h, for RUN 8.4±1.3 h and for REST 8.4±1.3 h). The maximum difference in the starting time of recording between the three days was, on average, 45 minutes (range 5-105 min).

The distribution of time spent at different activity and intensity levels for the whole group and for each individual for the 50 min period and for the whole recording days are shown in following chapter. Both STR and RUN exercise bouts contained different proportions of inactivity (STR $p=0.031$, RUN $p<0.001$), moderate (STR $p=0.048$, RUN $p<0.001$) and high (STR $p=0.001$, RUN $p<0.001$) physical activity whereas in REST there were no significant differences in the recordings between 50 min period and the whole day. This confirms that the distribution of muscle activity is comparable. Overall, compared to REST, during STR and RUN exercise inactivity decreased and moderate and high activity physical activity increased.

7.1 Muscle activity patterns during 50 min training and comparable rest period

The average EMG amplitude (% of EMG_{MVC}) for STR training period was 6,4 (±2,3), for RUN training 10,6 (±4,5), compared to 2,6 (±1,5) of REST period. The average EMG amplitude was significantly higher for STR ($p<0.001$) and RUN ($p<0.001$) compared to REST. RUN had also significantly higher average EMG amplitude when compared to STR ($p=0.011$). The proportions of inactivity, low activity and moderate and high activity time during the 50-minute period of strength exercise, interval running exercise and without purposeful exercise are shown in figure 5 as average percentage of the total measurement time. There were significant differences found in the activity patterns. Both STR and RUN were found having significantly (STR $p=0.002$, RUN $p<0.001$) lower inactivity than REST, and STR had significantly more low activity (p=0.013) and RUN had significantly (p=0.003) more moderate activity than REST. Also, at high activity level both STR and RUN had significantly (p=0.001) more activity than REST. Most moderate and high activity and least inactivity was found with 50 min period of RUN, whereas comparable REST period contained most inactivity and least moderate and high activity. Moderate and high activity together comprises 31.2% of STR training and 62.7% of RUN training, comparable to only 14.7% of REST period. When comparing STR and RUN, significant differences were found with inactivity (p<0.001) with STR having greater percentage of inactivity and high activity (p=0.004) where RUN had greater amount of recorded activity.

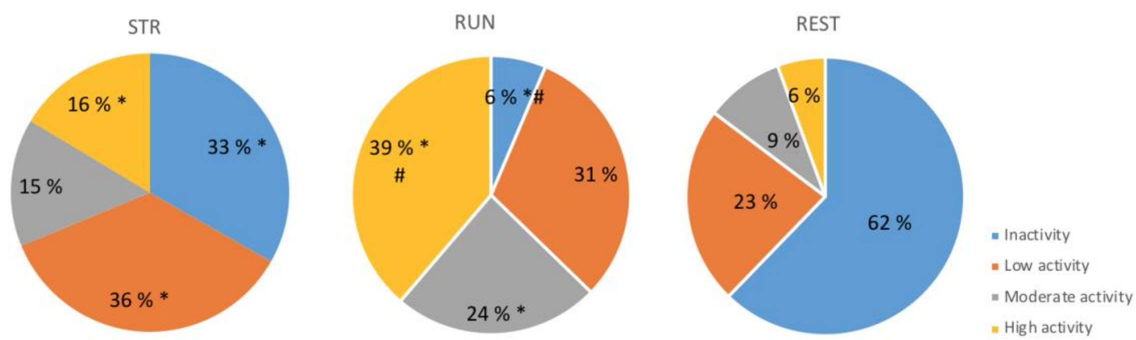
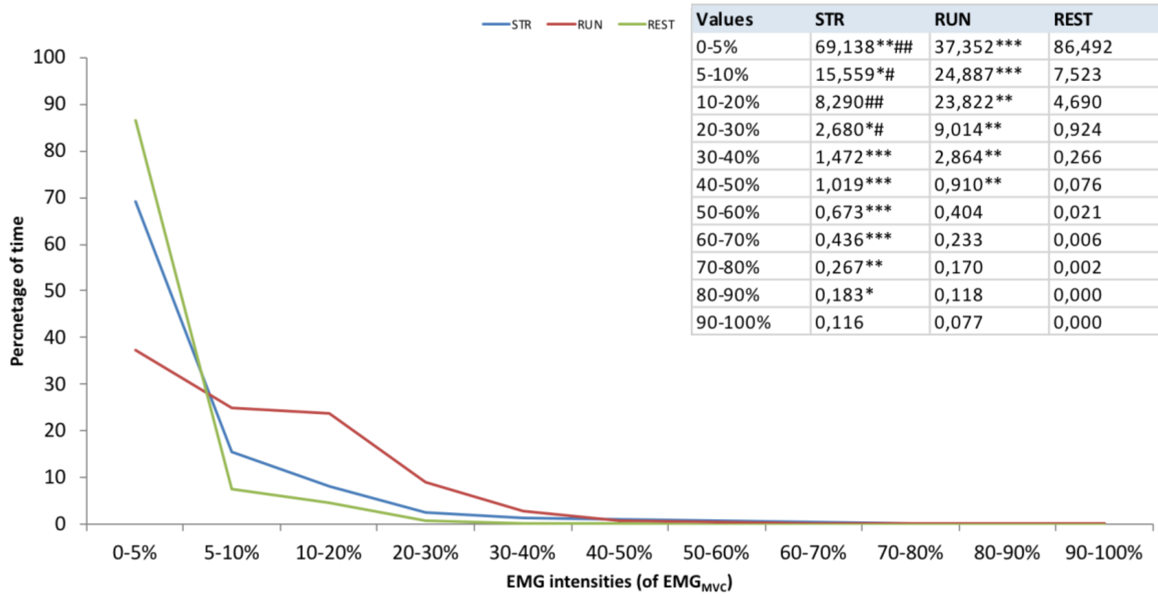


Figure 5. Proportions of inactivity, light, moderate and high physical during STR and RUN training sessions and comparable 50min REST period (average % of total measurement time). Significant differences to REST at * and significant difference between STR and RUN at #.

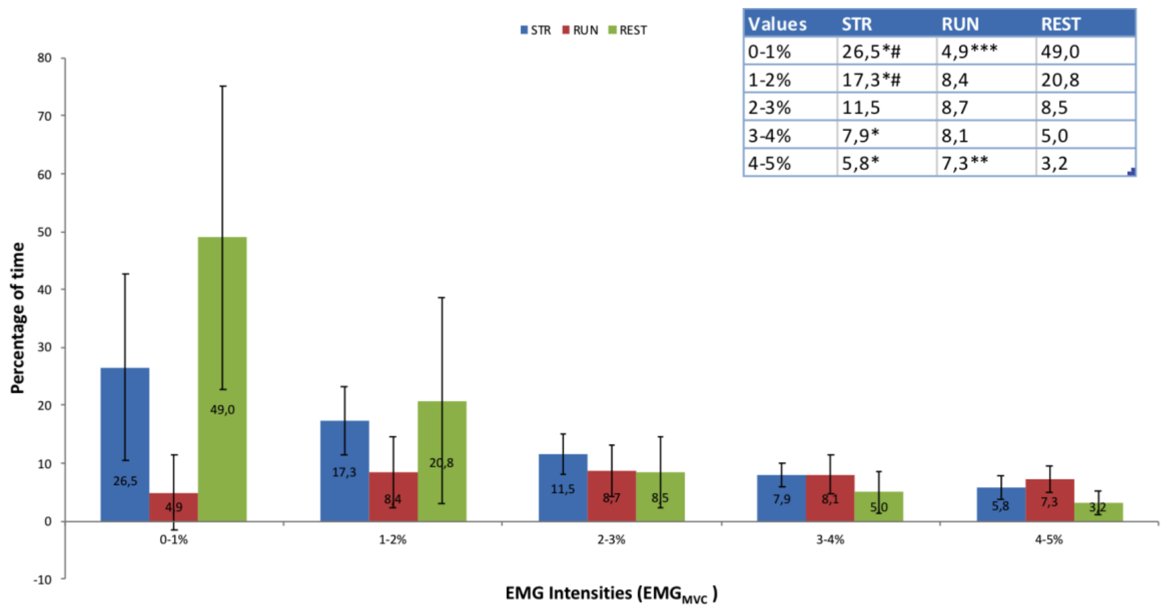
The distribution of different EMG_{MVC} intensities during 50 min STR, RUN and REST is shown in Figure 6. Significant differences were found at all muscle activity levels when comparing STR to REST and at activity levels below 50% when comparing RUN to REST. Comparison of the different EMG amplitude levels shows that amplitudes below 5% EMG_{MVC} were reduced and the proportion of higher amplitudes were increased as a response to STR and RUN. The differences between STR and RUN were significant only at levels below 30% EMG_{MVC}.



Values	STR	RUN	REST
0-5%	69,138**##	37,352***	86,492
5-10%	15,559*#	24,887***	7,523
10-20%	8,290##	23,822**	4,690
20-30%	2,680*#	9,014**	0,924
30-40%	1,472***	2,864**	0,266
40-50%	1,019***	0,910**	0,076
50-60%	0,673***	0,404	0,021
60-70%	0,436***	0,233	0,006
70-80%	0,267**	0,170	0,002
80-90%	0,183*	0,118	0,000
90-100%	0,116	0,077	0,000

Figure 6. Distribution of EMG intensities (of EMG_{MVC}) during 50min STR, RUN and REST period. Significant difference to REST at * p<0.05, p<0.01 and *** p<0.001. Significant difference between STR and RUN at # p<0.05 and ## p<0.01.

Figure 7 shows the distribution of different EMG_{MVC} intensities at 0-5% EMG_{MVC} in more detail. Activity below 3% EMG_{MVC} was reduced as and activity above 3% was increased a response to STR and RUN training sessions. Significant differences to REST found at intensity level 0-1% of EMG_{MVC} with STR (p=0.018), RUN (p<0.001), at level 3-4% and 4-5% with STR (p=0.021 and p=0.016) and at level 4-5% with RUN (p=0.003). When STR and RUN were compared, significant differences were found at levels 0-1% (p=0.002) and 1-2% (p=0.011) STR having higher proportion of activity.

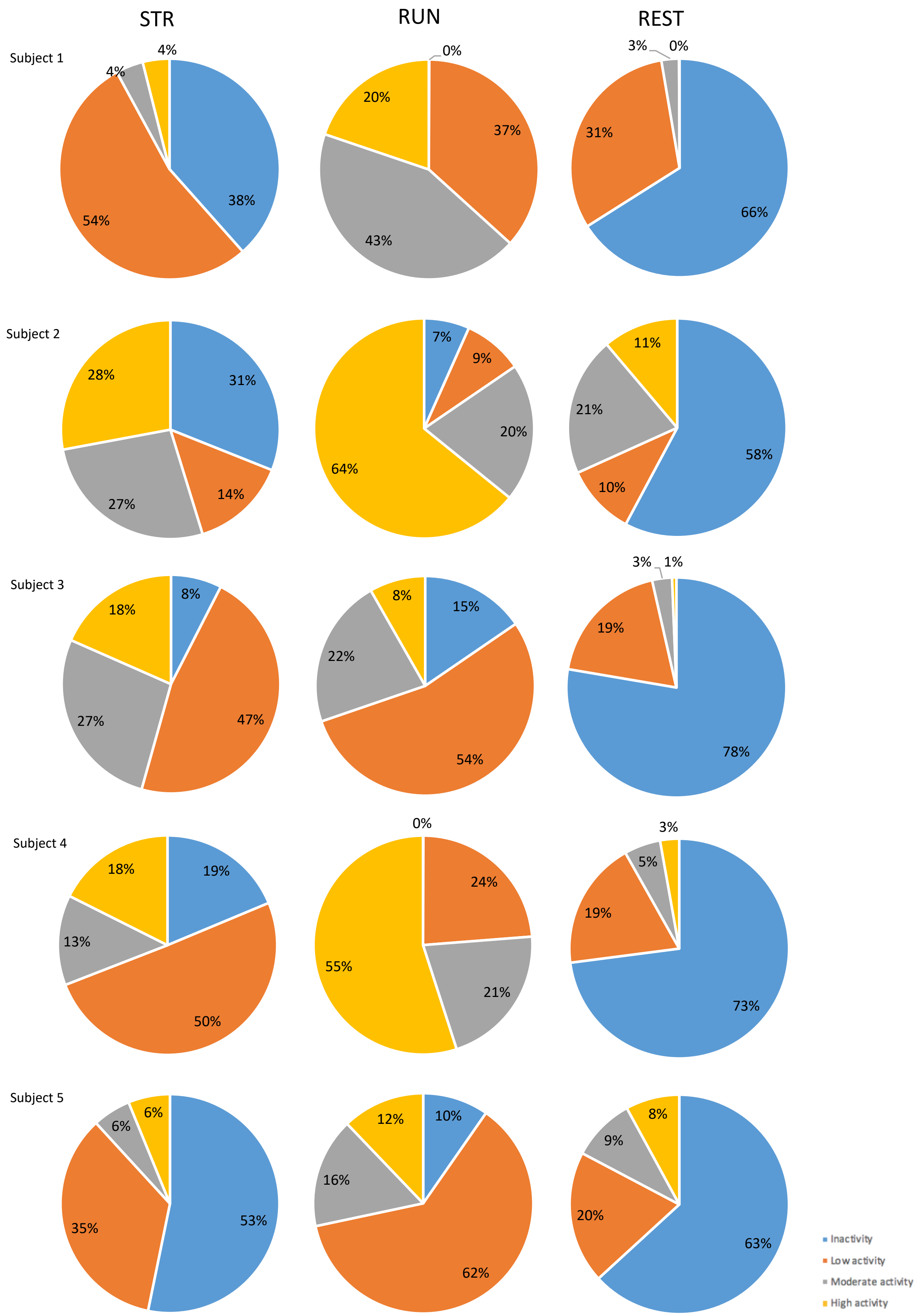


Values	STR	RUN	REST
0-1%	26,5*#	4,9***	49,0
1-2%	17,3*#	8,4	20,8
2-3%	11,5	8,7	8,5
3-4%	7,9*	8,1	5,0
4-5%	5,8*	7,3**	3,2

Figure 7. Distribution of EMG intensities (of EMG_{MVC}) during 50min STR, RUN and REST period at intensity levels below 5% of EMG_{MVC}. Significant differences to REST at * and between STR and RUN at #.

In both STR and RUN period, the EMG intensities above 100% (of EMG_{max}) were reached. In STR 0,15% and in RUN 0,17% of total time were spent at intensities above 100%, compared to 0% in REST period. However, differences between 50 min periods were not significant.

The activity patterns for each individual are shown in figure 8 for the 50 min STR and RUN bouts and comparable REST period. Variations between individual activity patterns can be seen. The largest variations between individuals were in the RUN low (average 30.9%, ±17.7%) and high activity levels (average 38.8%, ±21.0), in the STR low activity (average 35.5%, ±14.6%) and REST inactivity (average 62.2%, ±14.5%).


STR
RUN
REST
Subject 1
4%
4%
38%
54%
0%
20%
37%
43%
3%
0%
31%
66%
Subject 2
28%
31%
14%
27%
7%
9%
20%
64%
11%
21%
58%
10%
Subject 3
8%
18%
47%
27%
8%
15%
22%
54%
3%
1%
19%
78%
Subject 4
18%
19%
13%
50%
0%
24%
55%
21%
3%
5%
19%
73%
Subject 5
6%
6%
53%
35%
12%
10%
16%
62%
8%
9%
20%
63%
Inactivity
Low activity
Moderate activity
High activity

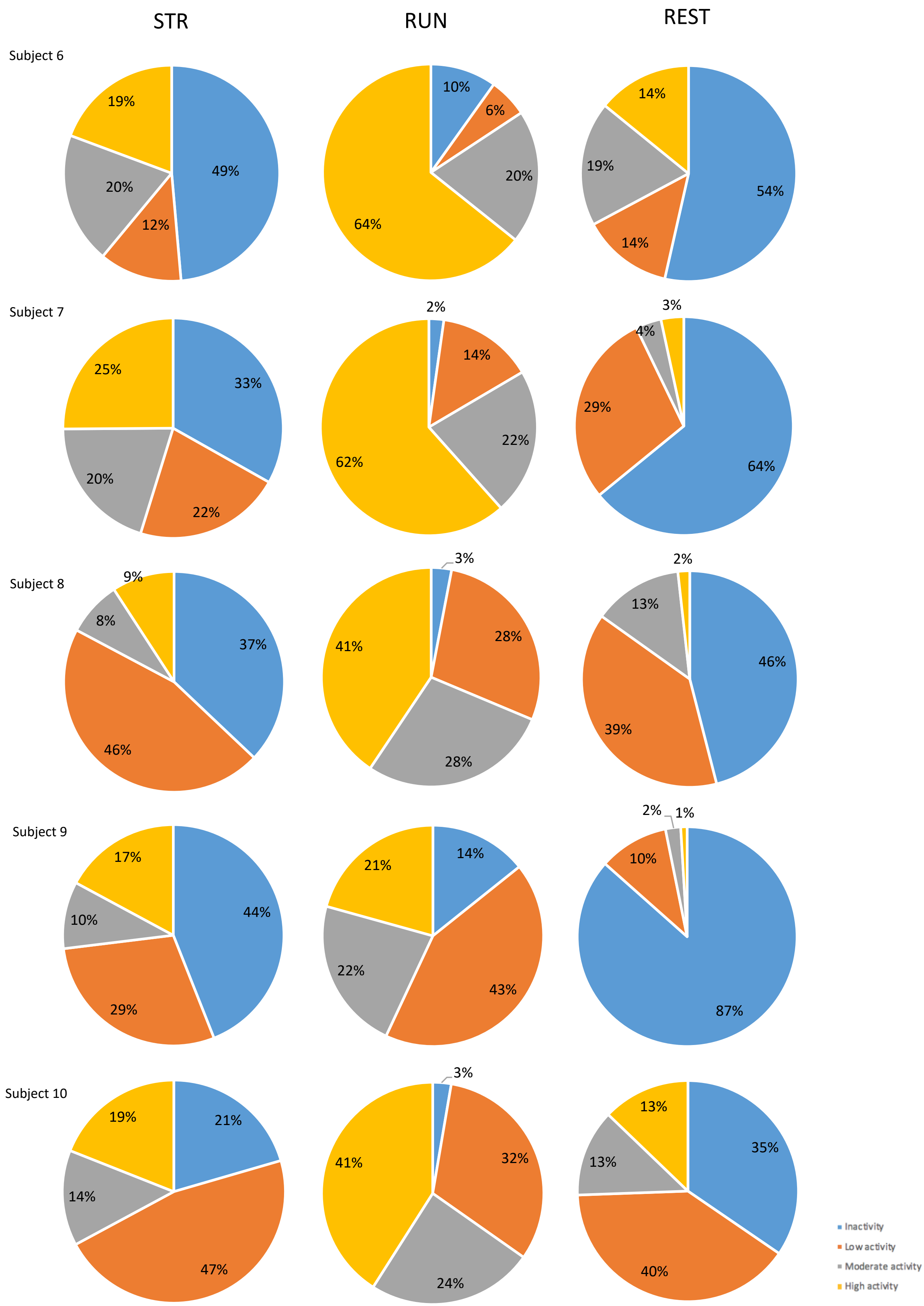


Figure 8. Individual activity patterns for 50 min STR, RUN and REST (as % of total measuring time).

7.2 Muscle activity patterns during whole days with and without exercise

The average EMG amplitude (of MVC) for STR was 2,8 (±1,3) and for RUN 3,0 (±1,3) during the whole recording day, compared to 1,8 (±0,7) of REST day, STR being significantly higher than REST (p=0.018). Figure 9 shows the proportions of different muscle activity patterns during the entire recording days for the whole group. Significant difference was found with STR day compared to day without exercise in the high activity (p=0,026) only. In general, days with STR or RUN exercise had less inactivity and more low, moderate and high activity time than REST day, but no other significant difference was found. No significant differences were found also when comparing days with STR and RUN exercise.

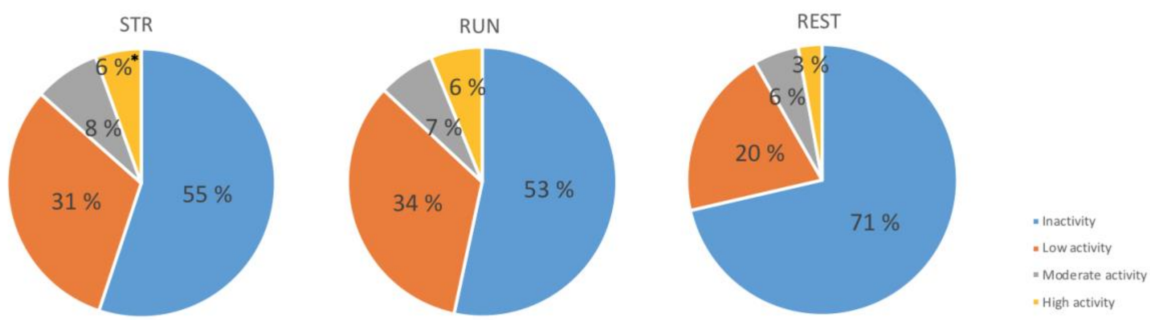
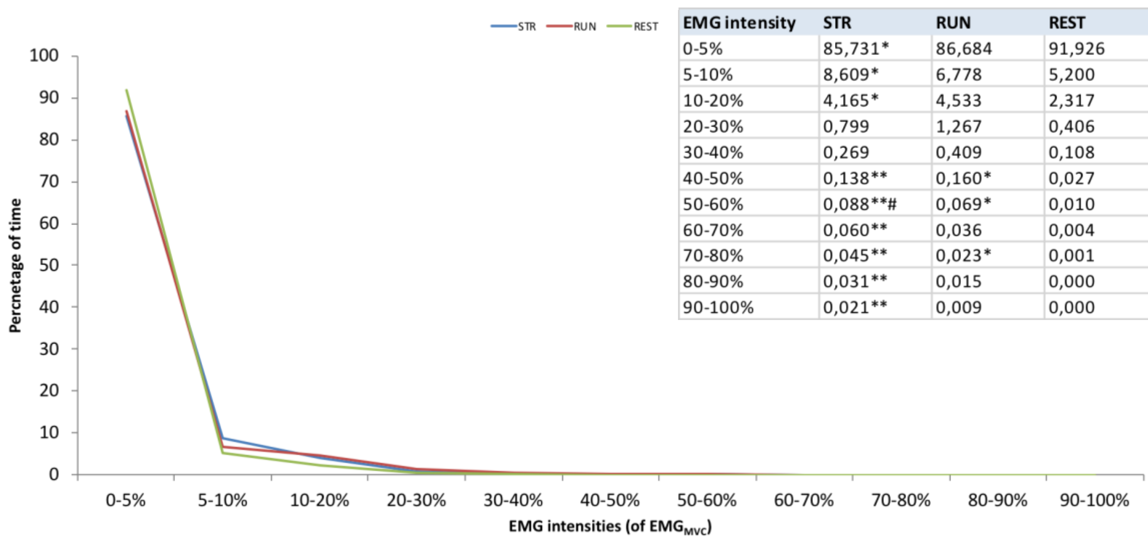


Figure 9. Distribution of inactivity, light, moderate and high physical activity during whole days (as % of total measuring time). Significant difference with STR-REST in high activity (p=0.026).

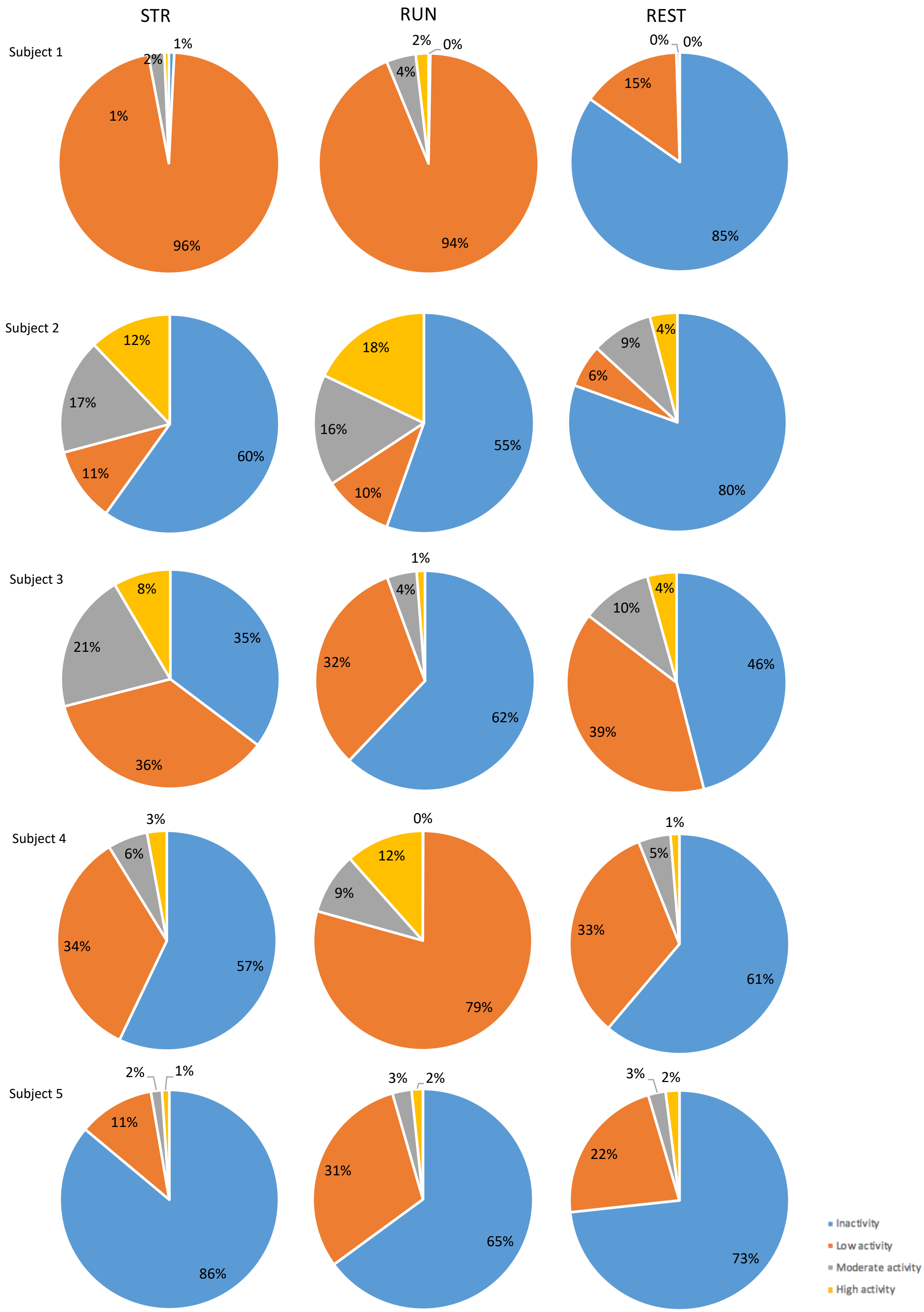
During the whole measurement time, increases in the muscle activity took place over the entire intensity spectrum as shown in figure 10. Almost all intensity levels in STR were significantly different from REST (intensities below 20% p <0.05 and intensities 40-100% p<0.01). Muscle activity below 5% MVC was reduced and above 5% MVC increased when compared to REST. Also, the interval running exercise significantly (p <0.05) altered the activity patterns, but only at intensity levels 40-50% and 60-80% MVC when comparing to REST. No significant changes were found between STR and RUN days other than for muscle activity at level 50-60% MVC (p=0.007) with STR having higher percentage of activity at this level.



EMG intensity	STR	RUN	REST
0-5%	85,731*	86,684	91,926
5-10%	8,609*	6,778	5,200
10-20%	4,165*	4,533	2,317
20-30%	0,799	1,267	0,406
30-40%	0,269	0,409	0,108
40-50%	0,138**	0,160*	0,027
50-60%	0,088**#	0,069*	0,010
60-70%	0,060**	0,036	0,004
70-80%	0,045**	0,023*	0,001
80-90%	0,031**	0,015	0,000
90-100%	0,021**	0,009	0,000

Figure 10. Time spent at different EMG intensities (relative to isometric MVC) during three different measurement days (time expressed as percentage of total measurement time). Significant difference with STR/RUN day compared to REST at * $p < 0.05$, ** $p < 0.01$, and between STR and RUN at # $p = 0.007$.

The individual distribution of different activity levels for the whole measuring days are illustrated in figure 11. It is shown that differences in the inactivity, light activity and moderate and high activity are highly individual. Largest variations between individuals were in the STR inactivity (average 55.1%, ±24.6%) and in RUN inactivity (average 53.4%, ±28.3%) and low activity (average 34.6%, ±28.8%). The differences in the moderate and high activity levels were within the range of 3% to 29% for STR day and 4% to 34% for RUN day compared 0-15% for REST day.


STR
RUN
REST
Subject 1
1%
2%
1%
96%
2%
0%
4%
94%
0%
0%
15%
85%
Subject 2
12%
17%
11%
60%
18%
16%
10%
55%
4%
9%
6%
80%
Subject 3
8%
21%
35%
36%
1%
4%
32%
62%
4%
10%
46%
39%
Subject 4
3%
6%
34%
57%
0%
12%
9%
79%
1%
5%
33%
61%
Subject 5
2%
1%
11%
86%
3%
2%
31%
65%
3%
2%
22%
73%
Inactivity
Low activity
Moderate activity
High activity

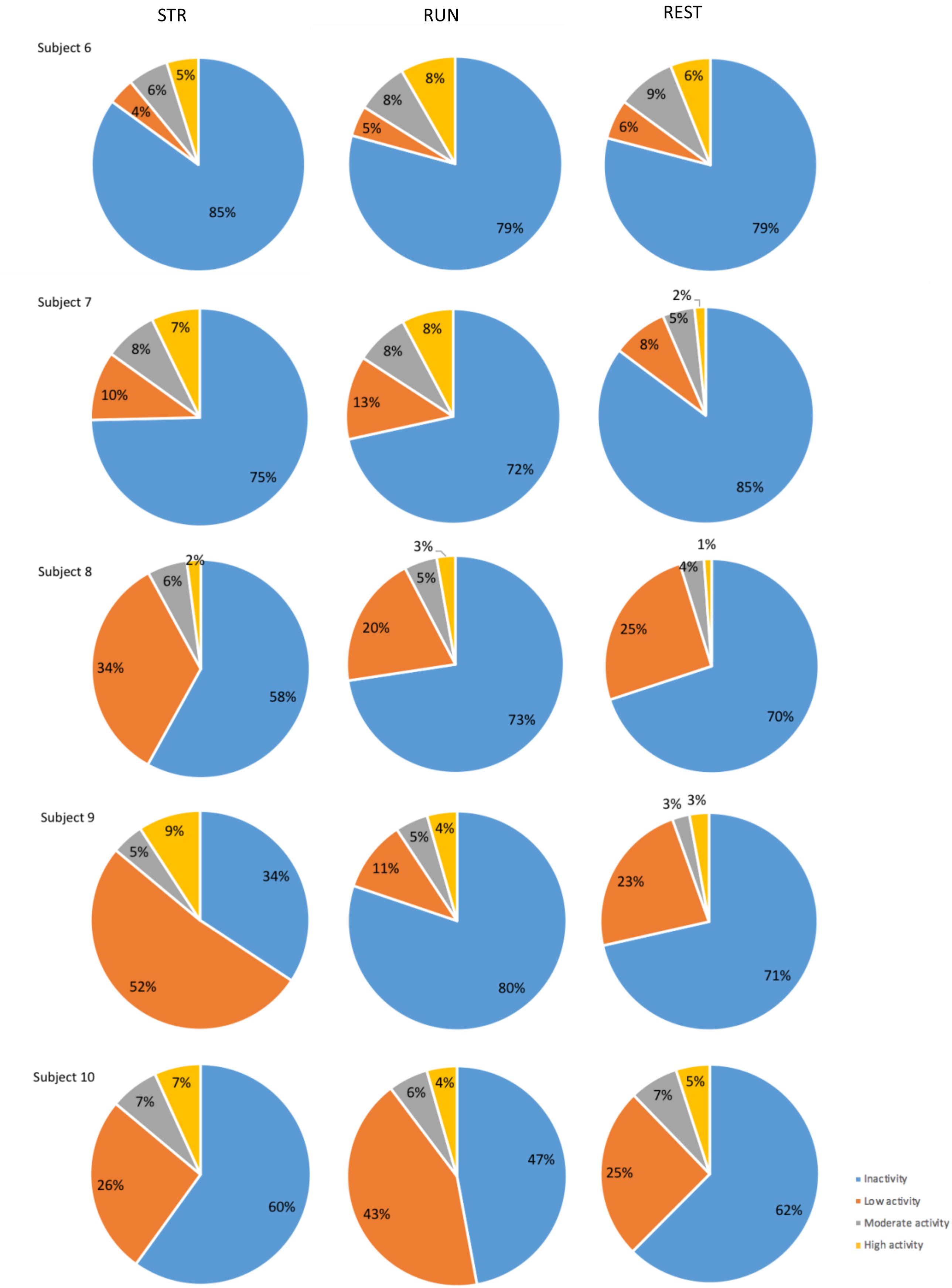


Figure 11. Individual distribution of activity levels for the whole STR, RUN, REST days

7.3 Association between physical activity and physical adaptation

The effectiveness of the training program was evaluated by measuring 3000 m running time and leg extension. The 10-week training program increased leg extension strength by 9.3±8,1% (p=0.008) and the 3000 m run times (pre-trial running time on average 842±54 seconds and post-trial running times on average 807±7 seconds) improved by 4±4% (p=0.014).

Associations between physiological changes and 50min training sessions and comparable 50 min REST period are illustrated in Appendix 1 for strength improvements and in Appendix 2 for 3000 m running time improvements. No association was found with strength and inactivity, low and moderate activity on STR (pictures a, b, c) or RUN (e, f, g) or REST period (pictures i, j, k) and with high activity on REST (picture l). A positive and significant correlations on maximum strength were found with exercise on high activity level on both RUN (picture h, p=0.039, r=0.657) and STR (picture d, p=0.030, r=0.683) periods. Also, no association was found with 3000m running times and any of the activity levels on STR (pictures a, b, c, d) or RUN (pictures e, f, g, h). Significant and negative correlation (p=0.038, r=-0.659) was found with 3000 m running time and higher inactivity on REST period (picture i). No association was found with other activity levels on REST period (pictures j, k, l).

Appendix 3 shows correlations between strength improvements and physical activity for STR, RUN and REST days. A negative correlation to strength improvements was found with higher percentage of inactivity on RUN day (picture e) and low activity on STR (picture b) and REST (picture j) days, but not at significant level. Positive, but not significant association also with higher inactivity on STR (picture a) and REST (picture i) days and with higher low activity on RUN (picture f) on RUN day. Higher activity at moderate and high PA levels had positive correlations also on all 3 days (pictures c, d, g, h, k, l). However, significant association with increase in the strength and physical activity was found with moderate (p=0.006, r=0.791) and high activity (p=0.013, r=0.749) on RUN days.

Associations with 3000 m running times and physical activity on STR, RUN and REST days are shown in Appendix 4. With STR and RUN days a positive association can be seen with 3K run improvement and higher inactivity (picture a and e) and negative correlations were found with low (picture b and f), moderate (picture c and g) and high activity (picture d and h). When looking at REST day, negative association was found with higher inactivity (picture i) and moderate activity (picture k) and positive correlations with 3k improvements were found with low (picture j) and high activity (picture l). However, none of these correlations were significant at day level.

8 DISCUSSION

Strength and interval running training sessions were both found to increase average EMG amplitude and to increase muscle activity time at EMG intensities below 50% MVC. Strength and interval running training had distinct activity patterns, and both of them reduced the muscle inactivity time, but only strength exercise increased the time spent also at intensities above 50% MVC. Both training modes induced positive results on improving maximum strength and 3000 m running times.

According to hypothesis, this study showed that an exercise bout of either strength training or interval running was found to increase muscle activity at all levels and to lessen inactivity when compared to similar period of a day without exercise. Both STR and RUN exercise was also found to increase the average EMG amplitude when compared to REST period. Strength and running exercise sessions were also found to have distinct activity patterns. In the STR moderate and high muscle activity together, and both light activity and inactivity all counted for about one third of the total activity profile, whereas in the RUN moderate and high activity contributed to over 60% and light activity over 30% of the total exercise time. Also, while the inactivity time in both exercise sessions was less than in REST, it was still 80% less for RUN compared to STR, despite the fact that interval RUN training sessions contained resting periods between the intervals. Exercise sessions of equal time can, therefore, constitute to varying time of moderate and high muscle activity. Contrary to hypotheses, both in STR and RUN exercise near maximum and supramaximal (of EMG_{max}) intensity levels were reached.

When considering the whole day, only strength training had a significant effect increasing the overall EMG amplitude and high muscle activity in particular. Overall, both STR and RUN days had less inactivity and more light, moderate and high activity than REST, which supports the hypothesis. This was the general trend however, and it was found that response to exercise and the redistribution of EMG intensities is highly individual. It seems that although during training the muscle activity patterns changed considerably, neither strength or interval running training had systematic effect on the muscle inactivity during time outside of training sessions. These results imply that although inactivity was reduced during training, training does not decrease total daily inactivity, but on the other hand, is neither compensated by increased inactivity in the group of healthy young adults, which is according to the hypothesis. Although the main aspect of this training intervention was not to increase daily physical activity, results match with observations from earlier studies in that structured exercise do not automatically increase daily activity or decrease inactivity and that sedentary time and moderate to vigorous physical activity are poorly correlated (Wasenius, 2014, Craft et al. 2012, Finni et al. 2014)). Muscle inactivity occurring in typical sedentary activities dominates the daily activity patterns even when subjects were participating in well-designed exercise program.

There is evidence to support the benefits of physical activity on health and prevention of disease. But the needed volume and intensity to induce physical adaptation has been somewhat unclear. According to hypotheses, in this study the muscle activity patters were found to be related to one of the measured physiological changes, the strength improvements, especially those of the training session. The results indicate that the more there is HIGH physical activity in the training session, the greater is the increase in the maximum strength. Results were the same both for STR and RUN exercises, suggesting that type of exercise does not matter, as long as intensity of exercise is high enough. This somewhat follows the predominant opinion that for skeletal muscle hypertrophic adaptations, an intensity greater than 60% of 1RM is needed, as only with higher intensities the larger motor units are typically recruited, which is needed to maintain and improve neuromuscular function (Knuttgen, 2007) and is also in line with earlier study that commonalities of adaption are high, and not competing, with strength training and high intensity sprinting exercise (Balabinis et al, 2013). Also, it is supporting the notion that only exercise at high intensities allow realization of near maximal cardiac output which is needed for cardiovascular and peripheral adaptations as well (Bucheit & Laursen, 2013). Although no significant relationships were found between 3000 m run times and on STR or RUN (neither on 50 min nor day level), association was found inactivity during comparable REST period; the more inactivity there was, less improvement could be seen in the 3000 m running time. This might suggest that higher inactivity during REST may hinder the results to some extent. Also, as on average the 3000 m results improved during the training program, the overall higher muscle activity during RUN training may have resulted in increased aerobic capacity. This might suggest that concurrent training is suitable both for obtaining strength gain and positive endurance adaptations and that simultaneously training for both strength and endurance did not result in a compromised adaptation. This is also in line with the study by Balabinis et al (2003) that shorter duration high-intensity sprinting exercise did not result in strength or power reductions.

The harmful health consequences due to time spend inactive are independent of moderate and high intensity physical activity (Owen et al. 2010; Healy et al. 2011). This study showed that while both strength and interval running bouts increased the moderate and high activity time and decreased the inactivity compared to rest period, the effects of training were not reflected over the whole day. Although inactivity dominated also with subjects in this study, it showed that short term exercise bout can result in physiological adaptation, as seen with improved results in maximum strength and 300 m running time. Therefore, both the time spend inactive and participating in moderate to high intensity exercise should be addressed to reach optimal health benefits.

Subjects' muscle activity recording time was relatively short in this study, average 9 hours for each day, which is main limitation of this study. The information about muscle activity before and after the recording took place, may have provided somewhat different results for the daily activity patterns. The comparisons of the activity patterns on days with and without structured exercise were made during normal life. The subjects were not instructed to do anything else than to participate the planned structured training sessions. No physical activity diaries were kept by the subjects, so the actual activities throughout the measurement days were unknown in this study, which is another limitation of the study. The measuring days may have contained more intentional exercise than the structured strength and interval running sessions, also during resting days. Also, a single measurement day could be during a weekday or on a weekend, when individuals' days may be somewhat different. The differences between weekdays and days on a weekend were out of scope for this study. The measured days in this study are only snapshots of reality and may not tell the absolute truth on daily physical activity of any individual.

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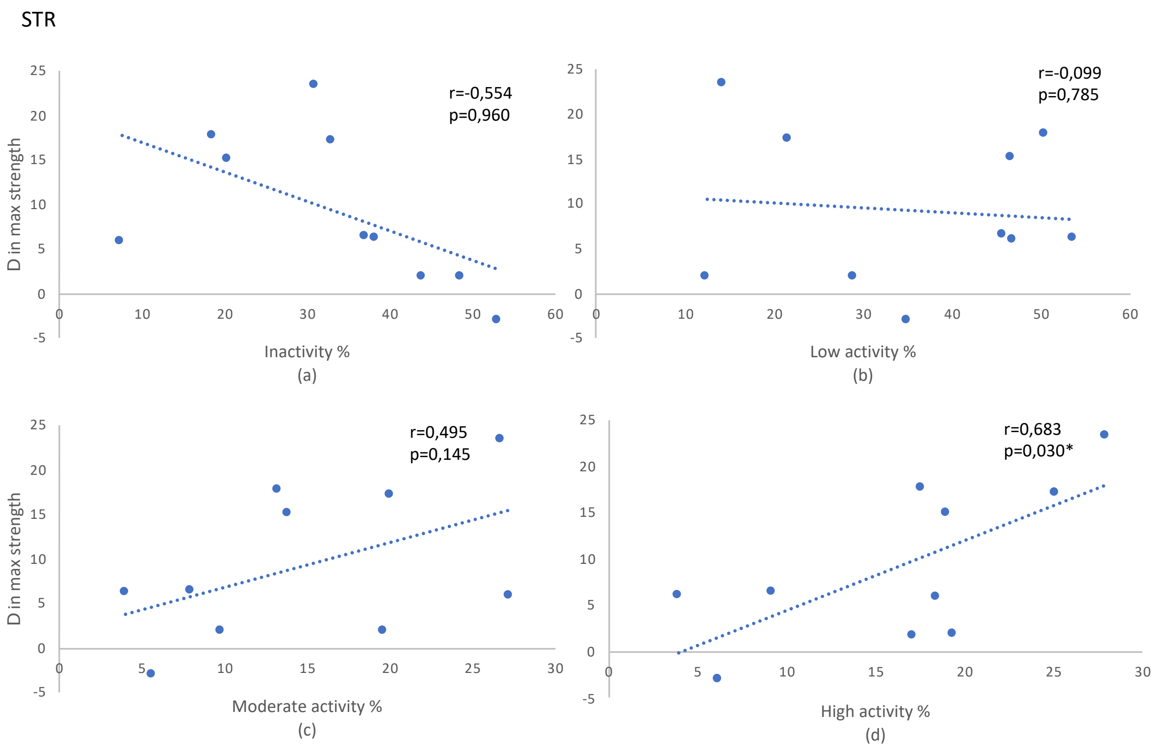
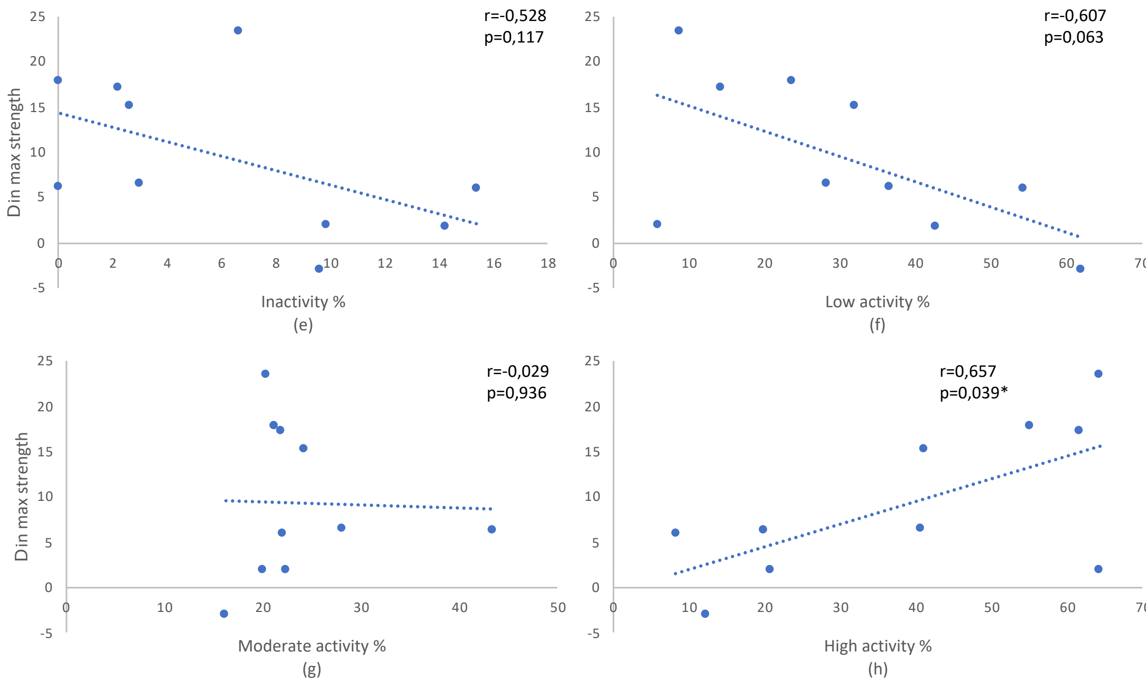
10 APPENDIX 1

Association change in maximum strength and activity levels during 50min STR, RUN and REST periods. Change (as percentage) in maximum strength on y-axis, percentage of specific activity on the x-axis.

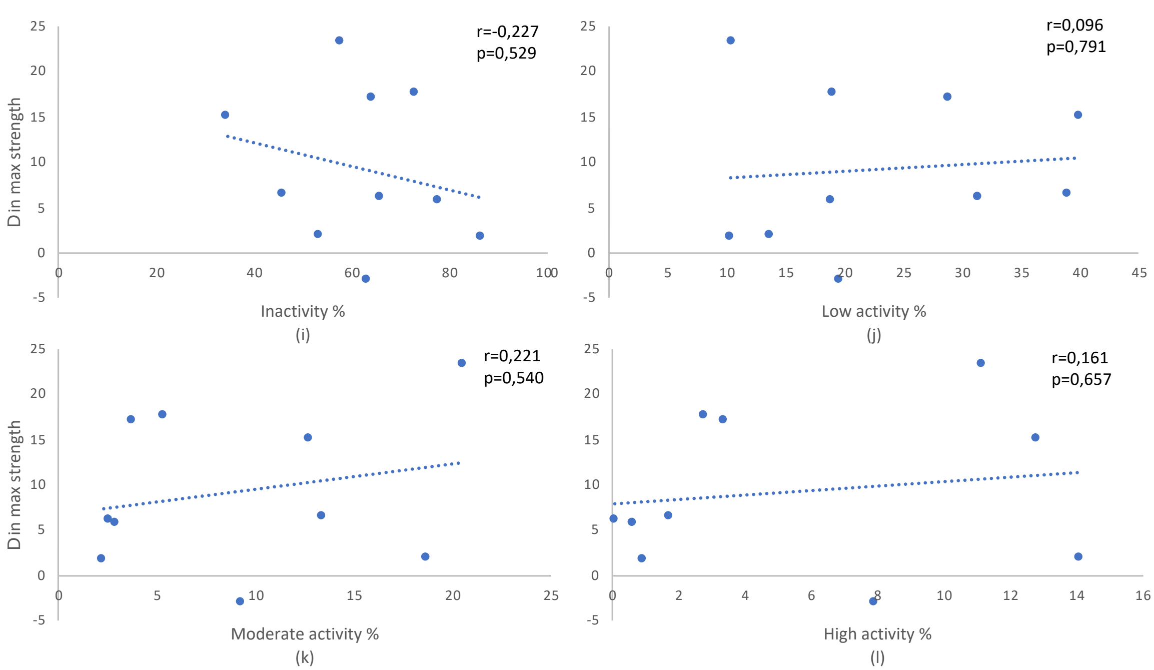


RUN



r=-0,528
p=0,117
Din max strength
Inactivity %
(e)
r=-0,607
p=0,063
Low activity %
(f)
r=-0,029
p=0,936
Din max strength
Moderate activity %
(g)
r=0,657
p=0,039*
High activity %
(h)

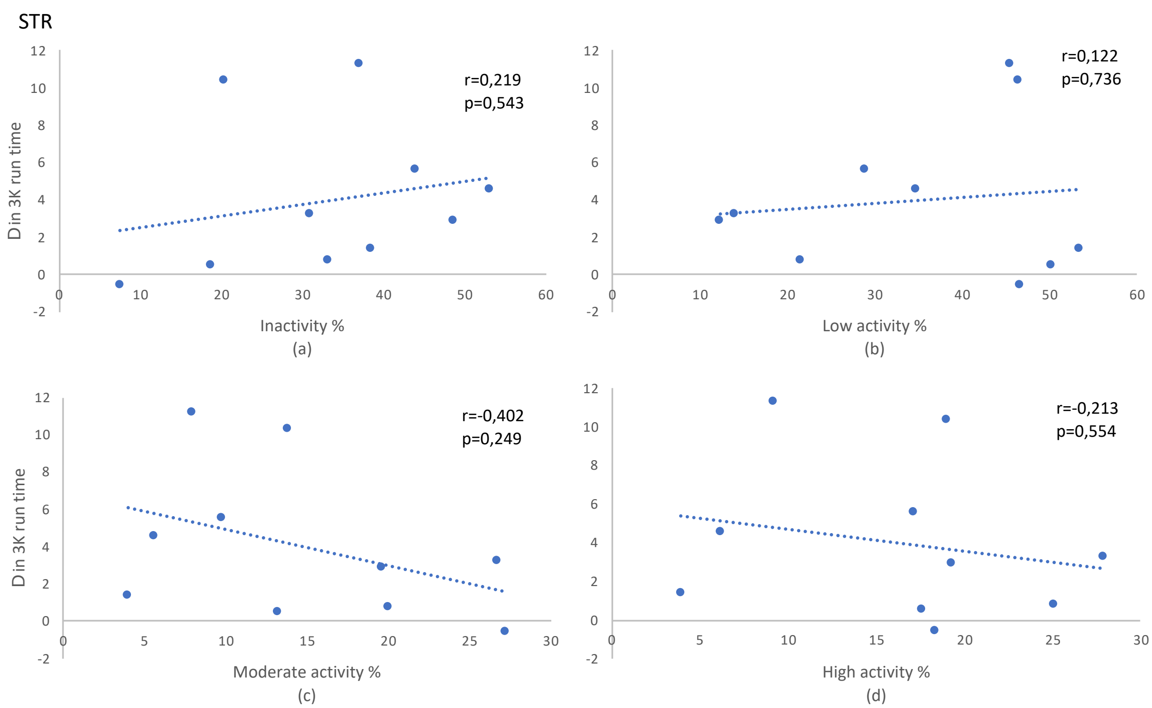
REST



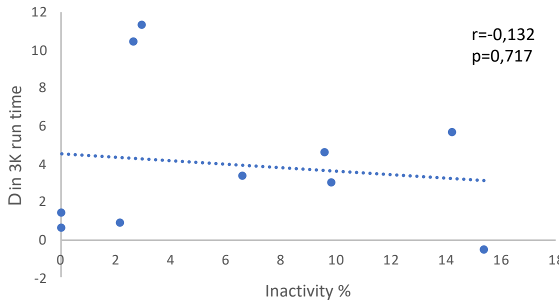
r=-0,227
p=0,529
Din max strength
Inactivity %
(i)
r=0,096
p=0,791
Low activity %
(j)
r=0,221
p=0,540
Din max strength
Moderate activity %
(k)
r=0,161
p=0,657
High activity %
(l)

11 APPENDIX 2

Association change in 3000 m Running time and activity levels during 50min STR, RUN and REST periods. Change (as percentage) in the 3000 m running time on y-axis, percentage of specific activity on the x-axis.



RUN



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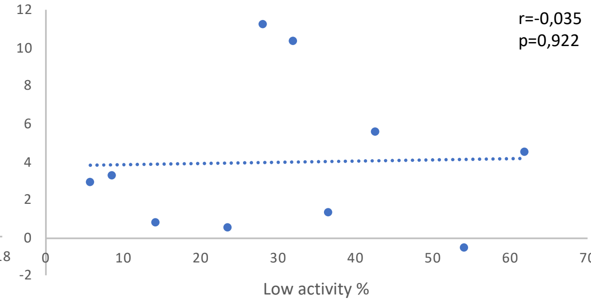

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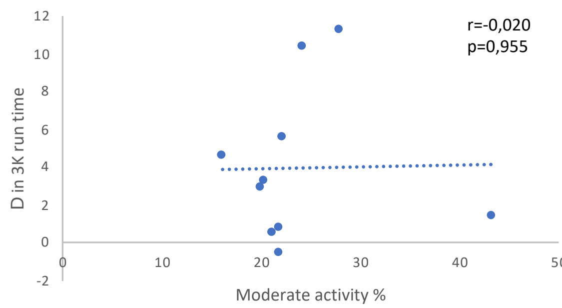

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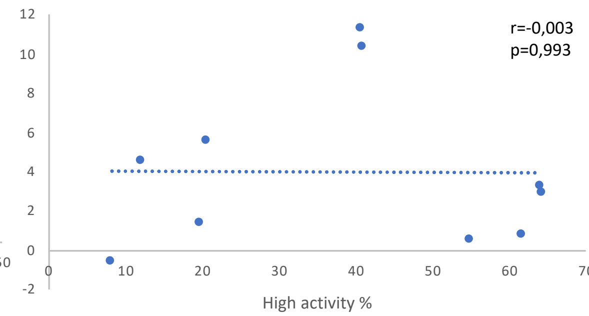
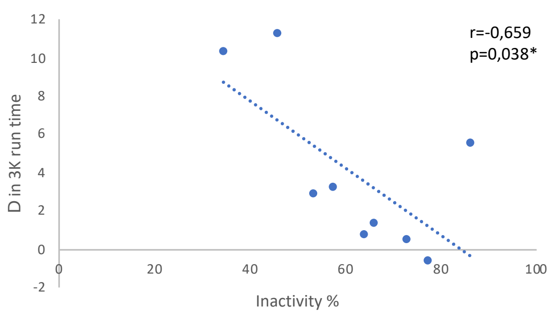


(h)

REST



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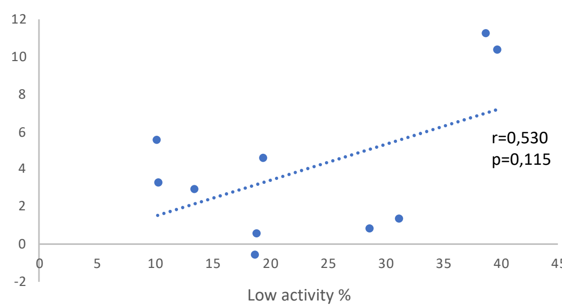
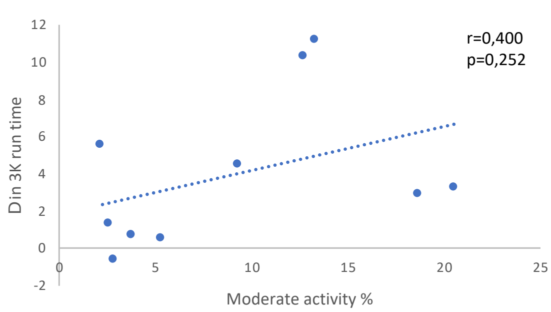
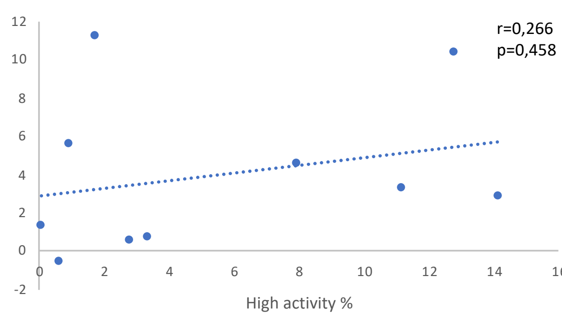


(j)



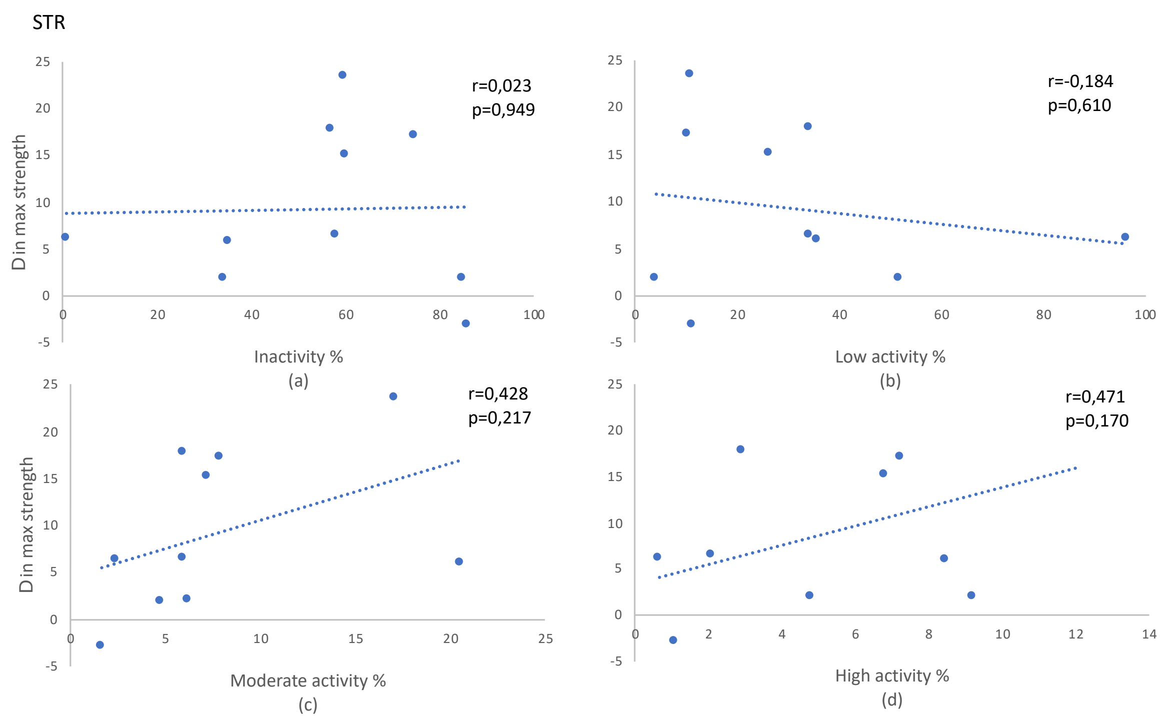
(k)



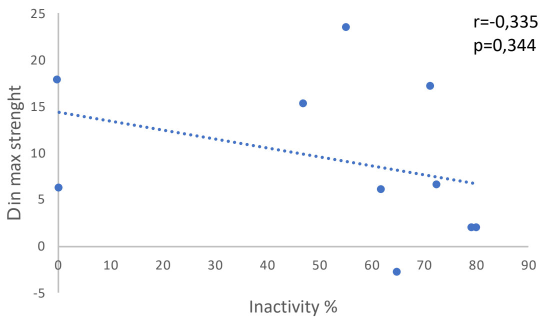
(l)

12 APPENDIX 3

Association with change in maximum strength and activity levels during whole days. Change (as percentage) in maximum strength on y-axis, percentage of specific activity on the x-axis.



RUN



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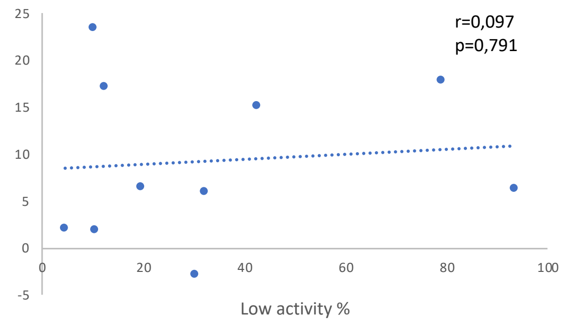

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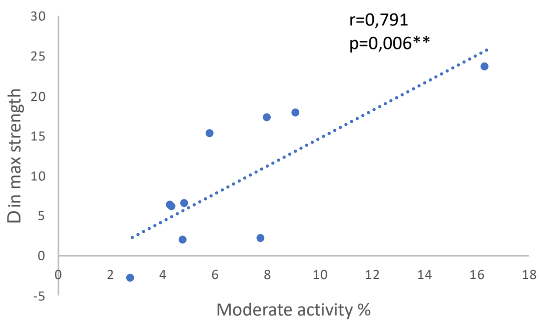

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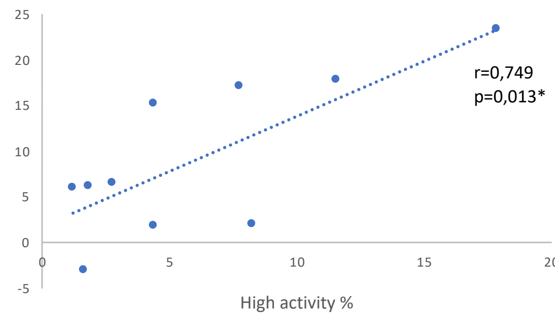
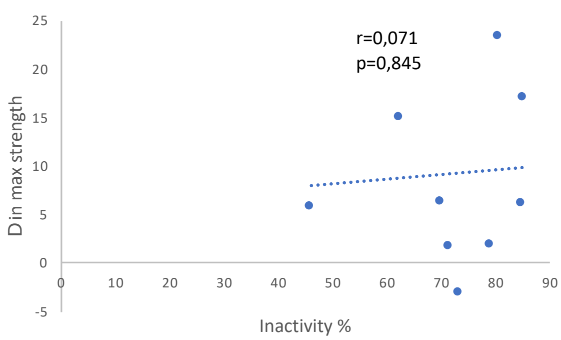
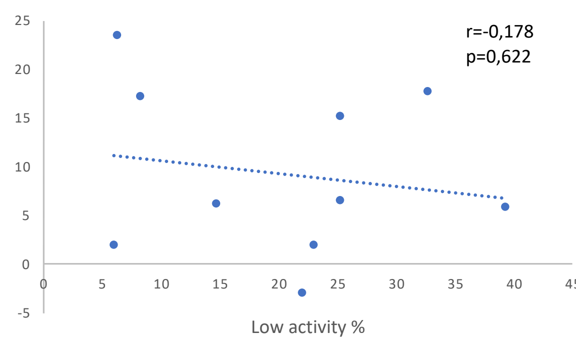


(h)

REST



(i)



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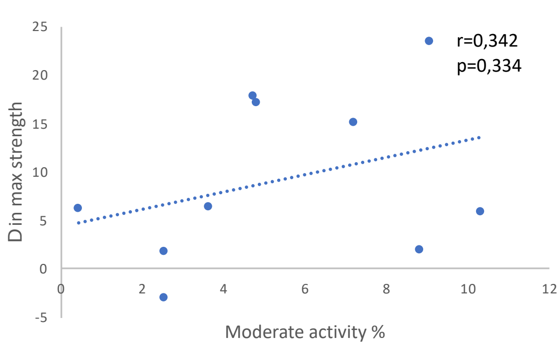
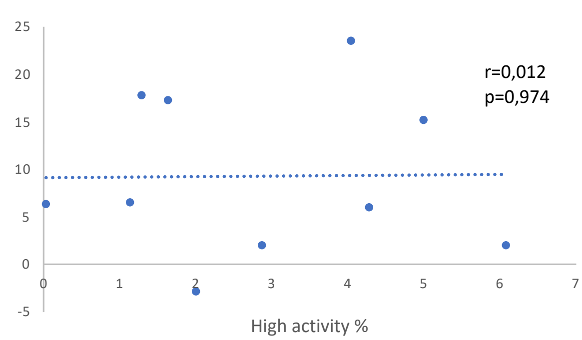


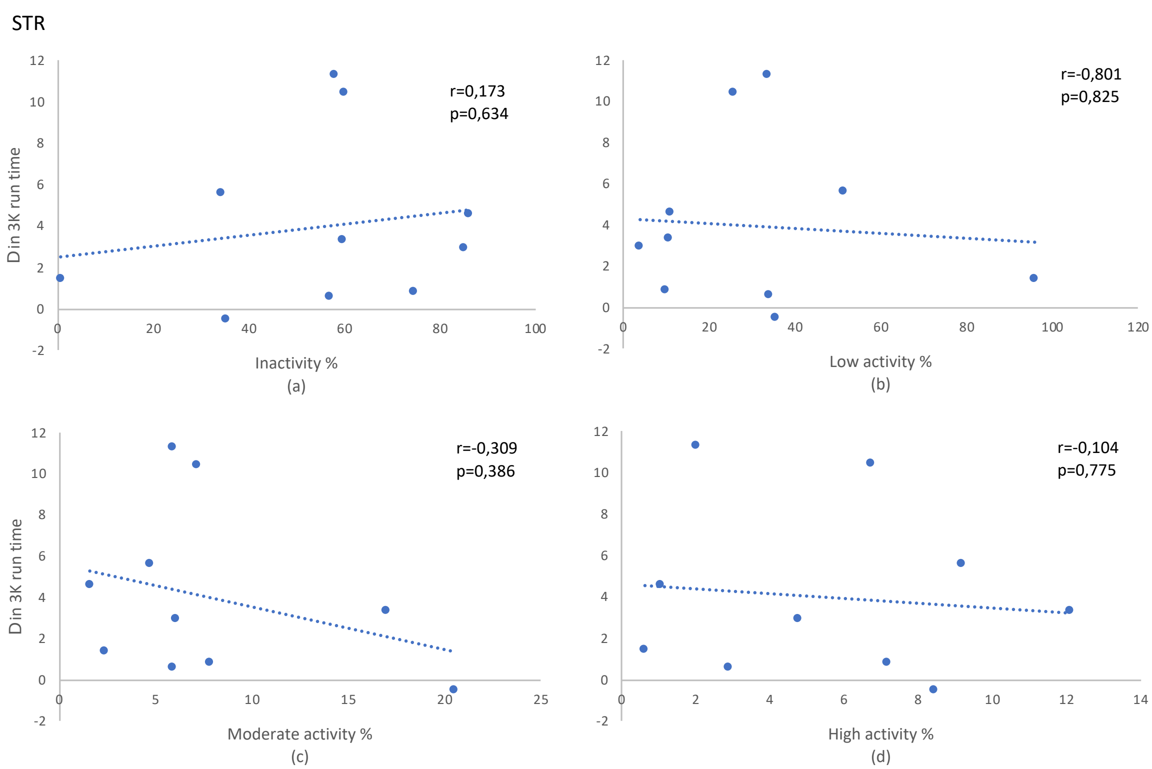
(k)



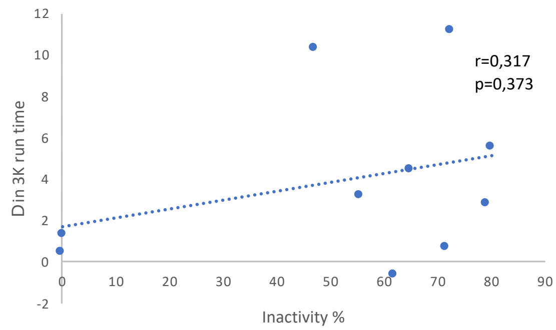
(l)

13 APPENDIX 4

Association of 3000 m running time and activity levels during whole days. Change (as percentage) in 3000 m running time on y-axis, percentage of specific activity on the x-axis.



RUN



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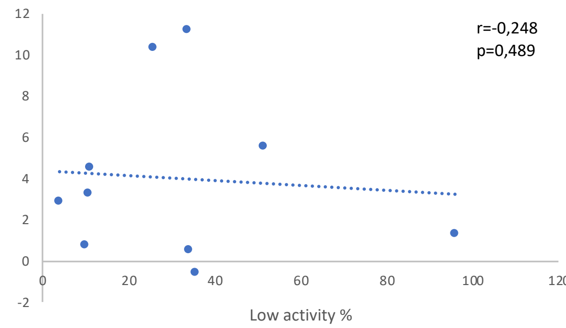

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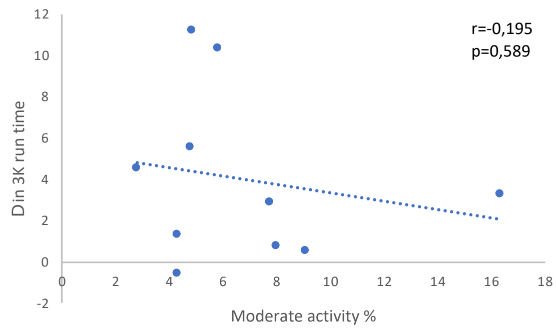

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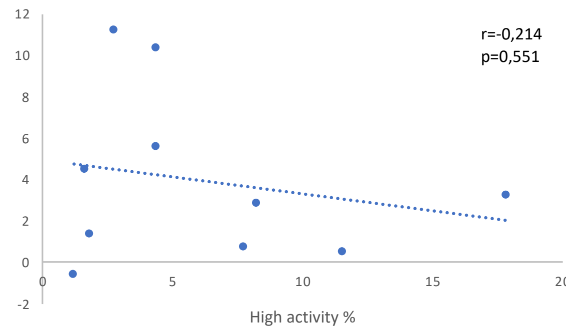
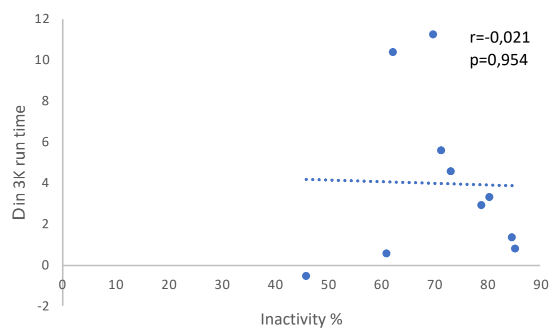


(h)

REST



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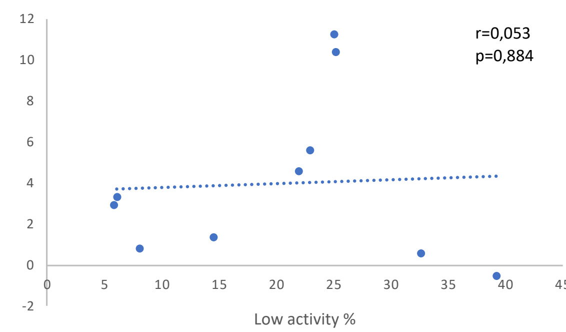

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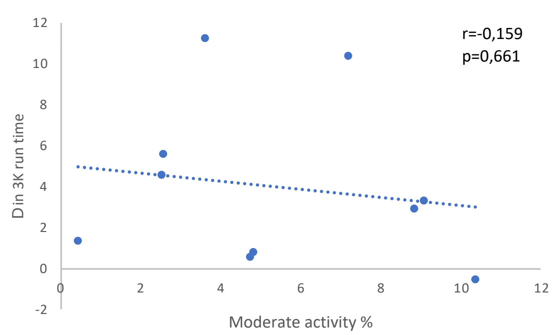

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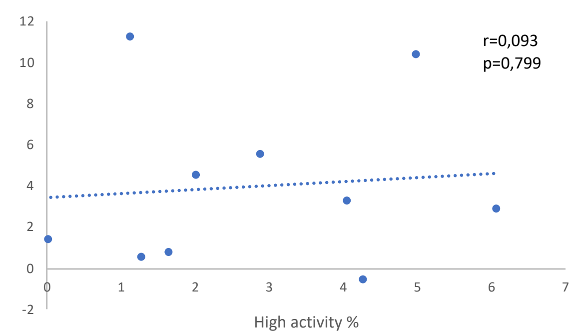

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