The effects on riding performance using active vs passive recovery during a simulated motocross race

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ABSTRACT

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The aim of the present study was to examine the effect of active and passive recovery methods in order to improve physical performance between motocross races. Exercise induced muscle damage post motocross racing was assessed as well.

Participants performed 2 races of 30 minutes with one hour break in between. During the break they performed either active or passive recovery protocols. Specific motocross performance outcomes and athlete's physical conditions were measured during, and before and after every motocross race. Lap times (LT) and heart rate (HR) were recorded during racing, and strength and power tests such as handgrip strength (HS), upper back pull (UBP), counter movement jump (CMJ) and medicine ball throw (BT) were performed pre and post racing. Metabolic demands and reaction time were evaluated pre and post race as well via blood lactate (BL) concentration, and a visual stimulus reaction time test (RT). Creatine kinase (CK) and strength test were assessed 24h after exercise bout.

No significant differences ($p>0.8$) in laptimes, and in force and power production (CMJ $p>0.1$; UBP $p>0.5$; HS $p>0.2$; BT $p>0.8$) were found, after using active or passive recovery in between races. A significant drop in HS was found when comparing pre and post race values (HS $p<0.0001$). RT was not affected by any of the recovery protocols but it tended to improve at every trial. 24 h post racing, baseline strength values were not recovered, and CK values were above resting levels.

The results of this study do not support the use of active recovery in between races when it comes to restoration of performance values. Motocross racing seem to cause some degree of exercise-induced muscle damage.

CONTENTS

LIST OF COMMON ABBREVIATIONS

BL: Blood lactate.

BT: Over head medicine ball throw.

CK: Creatine kinase.

CMJ: Counter movement jump.

EMG: Electromyography.

HR: heart rate.

HS: Handgrip strength test.

LT: Lap times.

RT: Reaction time test.

SD: Standard deviation.

UBP: Upper back pull.

1 INTRODUCTION

Motocross is the most practiced motorsport in the world, and still this sport remains on the shadow of MotoGP™ and Formula 1. That may be the reason why not much research has been done. The physical demands of sports like soccer, cycling or triathlon, are more clear thanks to the studies done (Bangsbo et al. 2006; Faria et al. 2005; Krustrup et al. 2007; Sleivert and Rowlands 1996), so the coaches have a scientific approach when comes to train and prepare these athletes.

Motocross racing is a technical sport, the rider has to manoeuvre the motorcycle in order to go as fast as possible on a dirt or sand track with corners, ruts, jumps, sand, mud, etc. The motored bike normally weights between 88 kg to 95 kg, and the horsepower (HP) ranges between 30 HP and 60 HP. Technical skills are the most important factor for achieving success; but the last few years the sport evolved and the physical aspect is becoming more and more crucial in order to perform. There is a common believe among society that motorcycle racing does not require any physical effort, but data shows the opposite. Compared to physical active subjects, motocross racers show higher values in upper and lower body strength, aerobic power and muscle mass (Gobbi et al. 2005). Konttinen et al. (2008) showed great activation values of different lower and upper body muscles during a simulated race, being the upper body muscles, the ones that produce higher electro myographic activity (EMG) values. Even the forearm values are higher during riding than a maximal handgrip strength test (Continent et al. 2008).

The total length of a motocross track varies from 1500 to 1750 meters, making it for lap times that range around 2 minutes. During the races 40 riders ride at the same time, and even more in practice, when only the best 40 racers will qualify for the main event. Racers achieve speeds well over 100 $km \cdot h^{-1}$ on the straights, but the track design cannot allow the average speed to exceed 65 $km \cdot h^{-1}$. Motocross racing can be considered a dangerous motor sport (Daniels et al. 2015), most of the racers suffer multiple traumatic injuries and head traumas during their careers (Daniels et al. 2015; Gorski et al. 2003).

A national championship motocross race consists of 1 or 2 practice sessions followed by 2 races of 30 minutes plus 2 laps. A world championship race gets underway during the whole weekend. Saturday schedule has 2 practice sessions and a 20 minutes race for the pole position, and on Sunday the racers perform 1 practice session and 2 races of 30 minutes plus 2 laps. In between races and practice there is at least 1-hour break.

2 PHYSICAL DEMANDS OF MOTOCROSS RACING

2.1 Muscular demands of motocross

Most of the muscular actions found in off road motorcycling are isometric when the rider accelerates and brakes smoothly, but normally the track is bumpy so the athlete has to absorb the shocks performing mainly eccentric actions (Ascensão et al. 2007; Konttinen et al. 2007). Also at the take off and landing of jumps, the rider has to absorb the impact, and usually that involves eccentric actions (Konttinen et al. 2007).

EMG values (Table 1) obtained by Konttinen et al. (2008) show that the common believe that motorcycle racers just sit on their bikes and twist the throttle is not true. Konttinen et al. (2008) used high-level racers and hobby racers to find out physiological and neuromuscular responses during a motocross bout at every participant maximal riding speed. As can be seen in figure 1, there is great activation of upper and lower body limbs, being the arm muscles the ones with higher EMG values. All the values were compared with the 30% MVC results obtained by every subject in the laboratory. In the same table (Table 1) by Konttinen et al. (2008) finger flexors reached higher EMG values when riding than during an off the bike handgrip strength test MVC. This result has to be interpreted carefully since a lot of factors can influence EMG measurements (Farina et al. 2004).

TABLE 1. EMG values obtained during a motocross bout, compared to 30% MVC of different muscles (Konttinen et al. 2008).

	Vastus lateralis	Vastus medialis	Biceps brachii	Triceps brachii	Forearm flexors
Group A					
Landing	24##	38##	44	66##	91##
Braking	32##	36##	31	62##	116##
Ref sitting	4*	11	19	16*	40
Ref standing	8*	10	20	29*	31
Group H					
Landing	41#	42#	25#	74#	143##
Braking	45#	40#	29#	68#	178##
Ref sitting	5*	7	9	13*	69
Ref standing	13*	13	10	32*	37

#Represents the difference between landing and braking vs. reference riding values.
*Represents the difference between reference sitting and reference standing.
and *$P < 0.05$.
and **$P < 0.01$.

Konttinen et al. (2008) used wireless EMG, and the signal of this device can be interfered by noise produced by gadgets such as cell phones or fluorescent lights (Budinger 2003; Kamen and Gabriel 2010). Another limitation of this method could be the movement of the arm during motorcycle racing. This movement may induce crosstalk from synergist muscles, which can affect the results (Byrne et al. 2005). On the other hand, as the intensity of the contractions increases, the contamination from other muscles decreases (Kamen and Gabriel 2010). It is also important to mention that a motocross bout induces a considerable increase in catecholamine plasma levels (Ascensão et al. 2007), and an increase in epinephrine and norepinephrine seem to be important contributors to muscular force expression (French et al. 2008).

The higher EMG values were achieved when the racers had to reduce the speed by braking and when they landed the different jumps of the track (Konttinen et al. 2008). While the racers were in the air after a jump, the different muscles analyzed were more relaxed when compared with other situations in the track (Continent et al. 2008).

Comparing finger flexors' MVC before and after riding (figure 1), different studies show significant decreases in force (Konttinen et al. 2008; Konttinen et al. 2007). Also, Konttinen et al. (2008), found decreases in force of the leg extensors and arm flexors, but only in the hobby riders. Ascensão et al. (2008) performed similar tests to fifteen motocross races, and handgrip strength significantly decreased after the motocross bouts (Table 2).

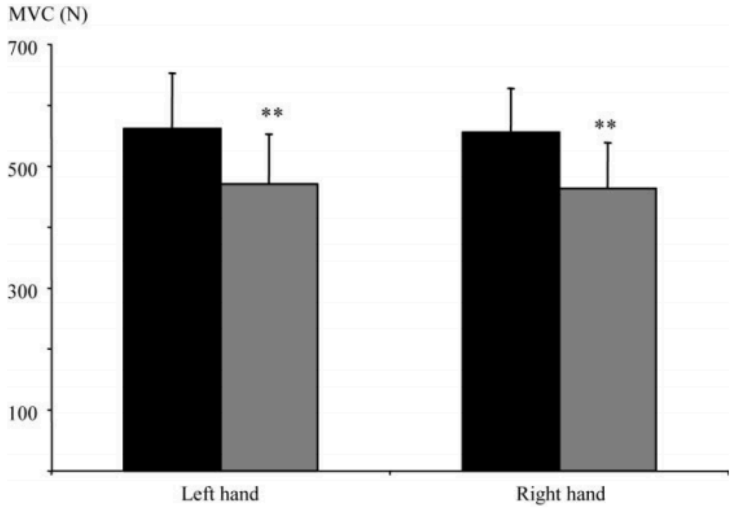


FIGURE 1. Handgrip MVC values (N), pre and post motocross bout (Konttinen et al. 2007).

In the study from Marina et al. (2011), the authors tested road bike racers during a 24 hours relay race. They found decreases in MVC of the finger flexors (flexor digitorum superficialis) after the first relays, and the decreases were more accentuated as the race progressed and the racers spent more time on the race track. No changes in EMG amplitude were reported (Marina et al. 2011).

TABLE 2. Mean (±SD) values of the finger flexors MVC before and after a simulated 30 minutes motocross race (Ascensão et al. 2008).

Variable	Right		Left	
	Before	After	Before	After
Maximal strength (N.)	467.5±61.7#	396.9±51.9 * #	393.0±65.7	349.9±77.4 * #
Fatigue index (%)	17.06±7.8	18.4±6.4	16.2±9.7	14.5±7.5

*Before *vs* after (P<0.05); #right *vs* left (P<0.05).

The different results that show decreases in MVC of the finger flexors, after motorcycle riding (Ascensão et al. 2008; Konttinen et al. 2008; Konttinen et al. 2007; Marina et al. 2011), may suggest that muscular fatigue is significant after motorcycle racing, and specially in the finger flexor muscles. The high levels of activation and the decreases in force of the forearm muscles could be the cause of compartment syndrome of the forearm, which a large number of motorcyclists suffer (Goubier and Saillant 2003).

Ascensão et al. (2008) added one more test. They used an upper-limb Wingate test before and after the motocross bouts. The predominant energy system during an upper-body Wingate test is the anaerobic lactic system (Lovell et al. 2013). Peak power, mean power and relative power decreased significantly after riding, compared to the baseline values (Ascensão et al. 2008). According to Lovell et al. (2011), power values are the best indicators to upper-body Wingate performance, so it can be hypothesized that a motocross bout induces decreases in muscular strength. These results show once again that there is a decline in upper-body functionality after motocross racing.

2.2. Cardio-respiratory responses to motocross riding

Different authors obtained similar heart rate (HR) values during motocross racing. Most of the subjects tested in different studies showed that while riding, HR is near or even above maximal HR, when compared to laboratory tests (Ascensão et al. 2007; Ascensão et al. 2008; Konttinen et al. 2007; Konttinen et al. 2008). According to Konttinen et al. (2008), HR reached a steady state around the two minutes mark after the start of the motocross bout. In figure 2, it can be seen that during a simulated motocross race, racers HR is almost all the time above 85% of HRmax, and in the 90%-100% range during 87% of the time (Ascensão et al. 2008). Other studies in different motorsports such as car racing showed that drivers spend the majority of the races above 90% of their maximal HR (Matsumura et al. 2011). As it has earlier mentioned, Ascensão et al. (2007) found significant increases in plasma catecholamine levels, and this rise in epinephrine and norepinephrine can be one of the explanations of the near maximal HR, achieved by the racers (Zouhal et al. 2008). Apart from increasing HR (Zouhal et al.

2008), catecholamines produce a marked increment in glucose rate of production in the liver (Kreisman et al. 2001).

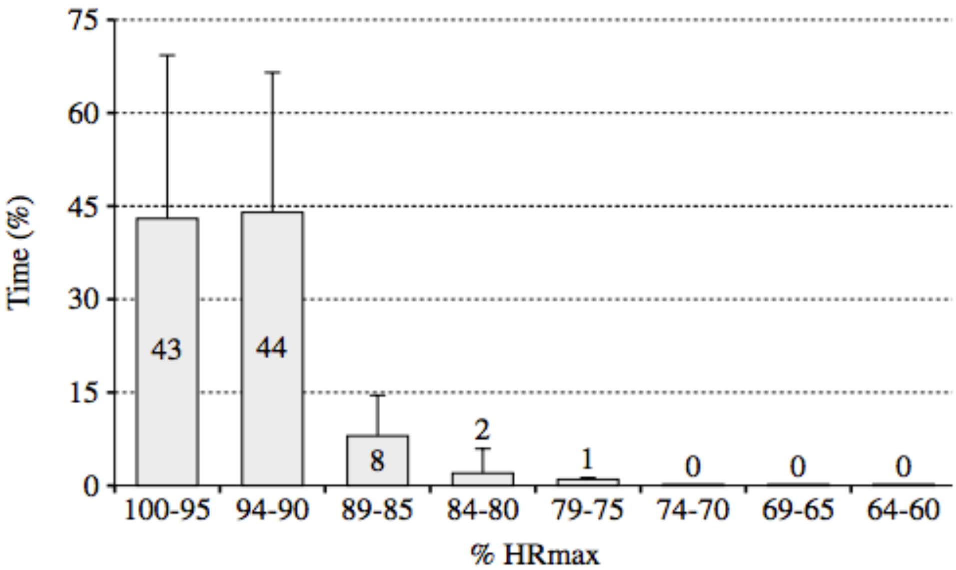


FIGURE 2. Time spent by the racers at different percentages of maximal heart rate (Ascensão et al. 2008).

Motocross athletes perform a lot of isometric muscle actions during riding (Konttinen et al. 2008), and it has been well documented that with isometric contractions that involve large muscle groups, increases in HR and blood pressure are found (Smolander et al. 1998).

Konttinen et al. (2007) used a gas exchange analyzer to assess oxygen consumption (VO_2) values during riding (Figure 4). Riders were previously tested on a treadmill in laboratory conditions, to determine their VO_2max. During the motocross bout the average VO_2 values of the participants was around 70% of VO_2max (Konttinen et al. 2007). In a more recent study by Konttinen et al. (2008), results showed a significant decrease in oxygen consumption as the simulated race went on in both high-level athletes and hobby racers. So participants VO_2 was higher in the beginning of the bout compared to the last minutes (Konttinen et al. 2008).

Muscle lactate and H^+ increases with increased exercise intensity, and this accumulation of lactate correlates with an increase in anaerobic metabolism (Gladden 2004). Lactate may have some effects in muscle fatigue but it seems that the decreases in force are most likely due to other physiological reasons like an increased extracellular osmolarity, causing water to exit the muscle fiber, and increasing intracellular ionic strength (Allen et al. 2008). Blood lactate samples can be taken in order to understand what happens in the muscle cell (Gorostiaga et al. 2014). Similar to what happened with HR, blood lactate (BL) values (Table 4) do not vary much in between different articles (Ascensão et al. 2007; Ascensão et al. 2008; Konttinen et al. 2007; Konttinen et al. 2008). All the BL concentrations due to motorcycle racing ranged from 4.0 $mmol \cdot l^{-1}$ to 5.7 $mmol \cdot l^{-1}$ (Ascensão et al. 2007; Ascensão et al. 2008; Konttinen et al. 2007; Konttinen et al. 2008). Konttinen et al. (2008) found that high-level racers achieved lower BL values, around 4 $mmol \cdot l^{-1}$, compared to hobby racers. These results suggest that faster motocross riders are more economical than slower drivers.

TABLE 4. Blood lactate values from different research articles.

Reference	Blood lactate values during motocross riding ($mmol \cdot L^{-1}$)
Ascensão et al. 2007	- 5.4 (1.2) $mmol \cdot L^{-1}$
Ascensão et al. 2008	- 3.9 $mmol \cdot L^{-1}$- 5.3 $mmol \cdot L^{-1}$
Konttinen et al. 2007	- 5.0+2.0 $mmol \cdot L^{-1}$
Konttinen et al. 2008	- Faster racers: 4.4 ± 1.8 $mmol \cdot L^{-1}$ - Slower racers: 5.7 ± 1.0$mmol \cdot L^{-1}$

Blood lactate values show that the most predominant metabolism is aerobic, with these BL values being close to the anaerobic threshold (Beneke et al. 2011). In a recent paper from Garcia-Tabar et al. (2015), the authors concluded that 90% of HRmax accurately predicts the onset of blood lactate accumulation of 4 mmol·l⁻ in professional handball, basketball, and futsal players. So HR can also indicate that motocross racing is predominantly aerobic, but again near the anaerobic threshold (Garcia-Tabar et al. 2015). In contrast, oxygen consumption during riding is around 70% of VO_2max, which according to Beneke et al. (2011) is found in athletes when they reach lactate concentrations above the onset of blood lactate accumulation.

Some of the studies already cited, also reported that the breathing frequency (Table 3) was near 100% during the motocross bout (Ascensão et al. 2007; Konttinen et al. 2007). Rusch et al. (1981) concluded that during maximal isometric contraction, blood pressure, heart rate and ventilation increase, and Konttinen et al. (2008) found high levels of activation in the forearm muscles.

TABLE 3. VO_2, ventilation, breaths per minute, heart rate, and blood lactate during 15 minutes ride on a motocross track. (Konttinen et al. 2007).

	$\dot{V}O_2$ (ml·kg^{-1}·min^{-1})	V_E (l·min^{-1})	RF (breaths per minute)	HR (beats·min^{-1})	BLa (mmol·l^{-1})
Ergometer (maximal)	45 ± 5	163 ± 22	55 ± 5	192 ± 6	13.4 ± 1.3
Motocross (absolute)	32 ± 4	118 ± 20	55 ± 9	184 ± 17	5.0 ± 2.0
Motocross (relative)	71 ± 12%	73 ± 15%	100%	95 ± 7%	37 ± 16%

3 ACTIVE AND PASSIVE RECOVERY

As it has been explained before, a motocross competition consists of different practice sessions and two races of 30 minutes during the same day, so effective recovery between races is important. Therefore, understanding the physiological demands of motocross racing, and develop adequate strategies to recover baseline performance level, is essential for coaches and athletes.

3.1. Active recovery

Active recovery or also often termed "cooling down" refers to submaximal exercise involving large muscle groups after a training session or competition (McArdle, Katch and Katch 2010, pp 173). This submaximal exercise is believed in some way to prevent muscle cramps and stiffness, and an enhancement of the overall recovery (McArdle, Katch and Katch 2010, pp173). There is a belief among the sports science field that active recovery allows for better performance during the next high-intensity exercise bout than does passive recovery (Abderrahmane et al. 2013).

High-intensity exercise is limited by fatigue, and the accumulation of blood lactate gives valuable information about the metabolic pathways used during the activity (Devlin et al. 2014). It seems that exercise intensities where anaerobic metabolism has an important role, and consequently blood lactate accumulates; active recovery may help its removal (Devlin et al. 2014). This removal will happen via increased perfusion of blood through other tissues that use BL as an energy source, like the heart, liver or inspiratory muscles (McArdle, Katch and Katch 2010, pp176). Active recovery at an intensity of 80% of lactate threshold seems to be superior compared to others intensities (Devlin et al. 2014). Active recovery shows faster lactate removal (Devlin et al. 2014), but lactate removal does not appear to be a valid indicator of recovery quality (Barnett 2006).

White and Wells (2015) found that with a mild active recovery, skiers performed better runs compared to the skiers that stayed still between ski runs. The control group (passive recovery, performed slower or longer ski runs compared to the active recovery group (White and Wells 2015). In another study from Ali et al. (2012) with professional swimmers, active recovery brought improvements in swimming performance compared to passive recovery. Swimmers who were assigned to passive recovery had slower times in the second swimming bout compared to the participants assigned to active recovery (Ali et al. 2012). During high intensity interval training, active recovery seems to be superior compared to passive recovery, to maintain the work capacity of the exercise intervals (Dorado et al. 2004). The results of the study from Dorado et al. (2004) show that active recovery resulted in a superior contribution of aerobic metabolism to the total energy turnover, and subjects assigned to active recovery performed more work in their 2^{nd} 3^{rd} and 4^{th} high intensity interval bouts. The difference in work in the last bouts was 13% and 9% greater than with passive recovery (Dorado et al. 2004). Greater O_2 availability may be one of the causes why active recovery may increase performance in the following exercise bout (Sahlin et al. 1979). Likewise, according to the article published by Lopez et al. (2014), active recovery is probably preferable when more than 2 exercise bouts are performed in the same session but, if only 2 high intensity wingate sprints are executed, passive recovery seems to be more beneficial to maintain performance.

In the paper from Taipale et al. (2015), military subjects marched on a treadmill at different intensities and inclinations. At the end of the high intensity walking, one group performed active recovery and another just sat on a chair. No differences were found in strength values in between groups, but the participants who performed the active recovery protocol showed statistically greater responses in testosterone, cortisol, and SHBG (Taipale et al. 2015). Also Losnegard et al. (2015) did not find any significant differences in performance, between active and passive recovery with cross-country skiers. Active recovery in between training soccer sessions during preseason did not bring any performance improvements to the participants, but subjects reported a decrease in muscle pain (Tessitore et al. 2007). Similar findings were reported from Rey et al. (2012), no differences between recovery protocols were found between soccer training sessions, but 24 hours after specific soccer training, passive recovery group perception of muscle soreness was higher.

3.2. Passive recovery

In the majority of studies, passive recovery means staying still after a training session or exercise bout. It is believed by some athletes that a total cessation of movement will effect negatively to their performance in the following exercise round.

Passive recovery does not differ much with active recovery on blood lactate removal (McArdle, Katch and Katch 2010, pp.175), and even if active recovery increases lactate removal, some authors concluded that it does not improve performance during repeated sprints (Balsom et al., 1992). It seems that active recovery is detrimental to performance in repeated sprint ability (Scanlan and Madueno 2016), even though Garner (2016) concluded that among basketball players there were no differences between passive and active recovery in sprint performance. Wahl et al. (2013a) found no differences in biomarkers using active and passive recovery after high intensity cycling bout. Another study with high-level junior triathletes showed that passive recovery is superior to active recovery in inducing performance improvements (Wahl et al. 2013b). Authors used active or passive recovery during high intensity interval training sessions in a 14-day training intervention, and researchers found bigger improvements in time trial performance and power output in the passive recovery group (Wahl et al. 2013b). The active recovery group performed 20% more training volume than the passive recovery group, since they were not stopping in the breaks between high intensity exercises (Wahl et al. 2013b). The decrements in performance in the active recovery group may be consequence of too much training volume.

Differently to most of the studies where researchers used high intensity exercise, Andersson et al. (2008) used active and passive recovery with female soccer players between matches separated by 72 h. No differences were found between recovery protocols (Andersson et al. 2008).

It seems that glycogen resynthesis increases significantly with passive recovery in all fiber types, while using an active recovery protocol does not affect glycogen resynthesis in type II fibers, but it is slower in type I muscle fibers (Fairchild et al. 2003). According to Fairchild et al. (2003), active recovery is associated with an unfavorable hormonal environment. These authors have shown lower plasma glucose and insulin levels, and high catecholamines concentrations, when compared to passive recovery (Fairchild et al. 2003). This slower glycogen resynthesis in type I fibers may affect performance negatively if a second exercise bout has to be completed some minutes or hours after the first bout.

So far there is not any articles that compares active and passive recovery in between motocross bouts or any other motorsports. The vast majority of studies use short bouts of high intensity exercise such as sprints, high intensity interval training and supra maximal cycling or swimming. The present study can clarify if active or passive recovery has the ability to enhance performance in between exercise sessions separated by a short period of time.

4 EXERCISE INDUCED MUSCLE DAMAGE

Exercise induced muscle damage affects the muscle cell by altering the organization of the myofibers, and resulting in decreases in strength and range of motion, soreness and swelling, and efflux of myocellular protein (Newham et al. 1983). This alteration of the muscle cell normally happens when subjects perform unaccustomed exercise and this effect is specially accentuated when eccentric muscle actions are executed (Newham et al. 1983). Exercise-induced muscle damage can impair performance for a few days if the overload is intense enough (Avela et al. 1999). In contrary with previous literature, some new research suggests that the amount of myofibrilar disruption is smaller than previously though and consequently not or less swallowing exists (Yu et al. 2013). This conclusion needs to be confirmed in further studies.

There are some ways to estimate muscle damage, but in this literature review the focus will be on creatine kinase and strength tests, as this will be the methods used to detect possible muscle damage in the present research paper. A recent literature review on exercise induced muscle damage (Warren et al. 1999) concluded that CK levels alone was not a good indicator, but comparison of strength levels between baseline and post exercise can provide meaningful data. Some other methods to detect disruption of the Z lines in the muscle cell after exercise are microscopic pictures and MRI (Clarkson and Hubal 2002), which are complicated and expensive processes.

Creatine kinase (CK) is an enzyme found in the cells that hydrolyses phosphocreatine to provide energy (McArdle, Katch and Katch 2010, pp 138). CK is mainly located in the areas of the muscle cell where ATP consumption or energy demands are high (Baird et al. 2012; Koch et al. 2014). CK is an accepted biomarker of muscle injury (Totsuka et al. 2002), but other studies showed no correlation between CK level and force decreases (Newham et al. 1987). Different CK isoforms provide specific information about the location of tissue injury such as brain injury, cardiac muscle damage, etc. (Koch et al. 2014). According to Baird et al. (2012) with heavy eccentric contractions and thus with large muscle damage, higher levels of CK are found in the bloodstream. When exercise damages the muscle cell structures, membrane permeability increases allowing CK to leak into the interstitial fluid, and then into the bloodstream (Brancaccio et al. 2007). In the review from Baird et al. (2012) it is mentioned that factors such as age, gender, or ethnicity can also affect CK bloodstream levels.

As previously mentioned, apart from CK, muscle strength tests are a good tool to measure muscle damage. Strength levels are measured before the sport event to set the baseline levels, and the same tests are performed again some hours after the exercise bout (normally between 24 and 72h post) to detect changes in strength levels (Peake et al. 2017).

In the article from Gill et al. (2006), it was concluded that rugby players that performed active recovery after a rugby match showed lower CK values than the group assigned to the passive recovery protocol. The subjects that executed active recovery showed 88.2% recovery when compared to individuals that did passive recovery, who were only 39.0% recovered (Gill et al. 2006). Therefore, CK levels were closer to baseline when active recovery was executed (Gill et al. 2006). In contrast, Wigernaes et al. (2000) found lower CK values on the subjects that performed passive recovery compared to the ones that stayed active after an uphill running test. Kraemer et al. (2001) data showed smaller CK levels in subjects that wore a compression sleeve after heavy eccentric exercise. Compression clothing seems to increase venous hemodynamics (Ibegbuna et al. 2003), thus increased blood flow could be one of the causes that showed lower CK values in the Kraemer et al. (2001) study. Taylor et al. (2015) also suggested that an increase in blood flow after muscle damaging exercise might be one of the reasons why CK values recover faster. They utilized neuromuscular electrical stimulation after an intensive training session, as this technique is capable of increasing blood flow (Abraham et al. 2013; Borne, Hausswirth and Bieuzen 2016). The group assigned to this recovery method had lower CK serum values at the 24-hour time frame, compared to the control group (Taylor et al. 2015).

5 PURPOSE OF THE STUDY

The purpose of this study is to examine the role of active and passive recovery between motocross bouts, and its effect on riding performance. This will be the first study to analyse different performance tests after using active or passive recovery between motocross sessions.

5.1 Research questions and hypothesis

1. Is active recovery superior to passive recovery when comparing performance values?

2. Does active recovery bring lower values of muscle damage? The author of the present study hypothesizes that active recovery protocol will not be superior to passive recovery on motocross performance values neither on muscle damage. Active recovery might be superior when sport bouts are separated by few minutes (Cheeran et al. 2008; White and Wells 2015) but it does not seem to affect performance positively when the breaks are longer (Tessitore et al. 2007). Likewise, if the participants had to complete more than 2 races in the same day, active recovery may be a good option as Lopez et al. (2014) suggest in their article.

3. Does motocross riding induce high levels of muscle damage? On the other hand, it is hypothesized that motocross racing will induce some degree of muscle damage. Newham et al. (1987) proved that after eccentric muscle actions there is greater muscle damage, and muscle actions during motocross riding are mainly isometric and eccentric (Konttinen et al. 2008).

6 METHODS

6.1 Subjects

Thirteen (n=13) elite and non-elite Finnish racers took part in this study. The average age, height, body mass and BMI of the participants was 33 ± 10 years, 179 ± 7 cm, 80.8 ± 10.0 kg and BMI 25 ± 2. Every subject performed active and passive recovery protocols on different days. Active and passive recovery sessions and testing were separated by 2 weeks in order to avoid accumulation of fatigue. The simulated motocross races were performed in the same race track so conditions could be as similar as possible. Test schedule was similar to a regular Finnish championship race schedule.

The participants were informed about the different protocols and measurements used in this study, and also about the risks and rights. Written informed consent was obtained from all subjects on the first day of testing and approval was granted from the University of Jyväskylä Ethical Committee. Participants with health problems or injuries were excluded from the study. All participants were in possession of insurance and racing license.

6.2 Overall design of the study

The riders performed two simulated motocross races (30 minutes) trying to emulate race pace, with one hour break in between. During the break the following recovery protocols were used: active and passive recovery. Active recovery consisted of 20 minutes at 60% of theoretical (HRmax=208-(0.7*age)) HRmax (Tanaka et al. 2001), on a cycle ergometer. Prior to all the field measurements, all participants performed a submaximal VO_2max test. HR was measured and used to control intensity during the active recovery protocol.

When subjects performed the passive recovery protocol between motocross races, they remained seated, without performing any type of physical activity such as walking, stretching, etc.

Different performance tests were done before and after the first motocross bout of 30 minutes. After the first post-test took place, the racers executed the assigned recovery protocol. Tests took place for the third and fourth time before and after the second simulated motocross race (Table 5).

All the subjects had the same sports drink during the break (0.5-1L. 70g HC, 0.08 mmolL Na), to make sure hydration and nutrition does not affect the results from active and passive recovery. Sleep and RPE will be recorded prior to the testing session. The different testing days had similar ambient conditions (± 5 ºC).

6.3 Measurements and analysis

The tests chosen to assess performance were handgrip strength (HS), counter movement jump (CMJ), isometric upper body pull strength test (UBP), medicine ball throw (BT), blood lactate (BL), HR (during the bout), RPE, reaction time (visual stimulus) and biochemical markers of muscle damage such as creatine kinase (CK). Pre and post simulated race HS, CMJ, UBP and BT tests were executed twice by the subjects with 30 seconds between.

Lap times are the most specific performance indicator, so all the lap times were recorded using a infrared sensors (J2Chrono Timekeeping Envoirment, Enymind Oy, Finland) and transponders placed on every bike. Each participant was encouraged to ride as fast as possible during the simulated races.

Handgrip strength is a widely used method, and according to Mathiowetz et al. (1984) it is reliable as long as the test is done seated, with the elbow at 90º of flexion and forearm in neutral position. This test has been used in numerous motorsports studies (Ascensão et al. 2008; Konttinen et al. 2008; Konttinen et al. 2007; Marina et al. 2011). Subjects completed the handgrip strength tests in a seated position and with their elbow at 90º of flexion. The device used was built at the Department of Biology of Physical Activity of the Jyväskylä University.

Lower body power was judged with counter movement jump. CMJ vertical velocity is associated with neuromuscular fatigue (Sanchez-Medina and González-Badillo 2011). The use of force plates on a motocross track might be a difficult task, because the uneven terrain. Therefore, to assess CMJ an infrared device to measure flight time was used (Department of Biology of Physical Activity of the Jyväskylä University, Finland).

Upper body strength and power tests were used to control riders' conditions before and after the exercise bouts. The research paper from Konttinen et al. (2008) shows greater EMG values from the upper body muscles when compared to the lower limbs. For this reason, the strength tests were more focused on the upper body muscle groups. Muscle power and strength recovers differently, being the first capacity the one that goes back to baseline levels faster (Thompson et al. 2015).

Subjects performed an isometric upper body pull strength test (UBP) test using a dynamometer to determine upper body strength (Department of Biology of Physical Activity of the Jyväskylä University, Finland), and a 5kg medicine ball overhead throw to determine upper body power. Subjects performed the UBP in a seated position, trying to simulate muscle actions found in motocross racing. Participants also executed the overhead ball throw (BT) in a seated position and with their backs against the wall. According to Haff et al. (1997), there is a good association between isometric and dynamic muscle actions when joint angles are similar. The authors also reported that isometric tests are reliable (Haff et al. 1997).

High-intensity exercise is limited by fatigue, and the accumulation of blood lactate gives valuable information about the metabolic pathways used during the activity

(Devlin et al. 2014). The assessment of BL is a good indicator of which metabolic pathway is the predominant during motorcycle riding. All the studies that tested motocross racers report similar BL values, and those range from 4.0 $mmol \cdot l^{-1}$ to 5.7 $mmol \cdot l^{-1}$ (Ascensão et al. 2007; Ascensão et al. 2008; Konttinen et al. 2007; Konttinen et al. 2008). Even though blood lactate removal does not seem a valid indicator of recovery state (Barnett 2006), greater O_2 availability from active recovery (Sahlin et al. 1979), may help to decrease anaerobic metabolism and increase aerobic metabolic pathways. Thus, BL values might be lower compared to the passive recovery group. BL was measured with a portable blood lactate monitoring system (Lactate Scout+, EKF, Cardiff, England).

HR was measured during the bouts, since it can be used as an indicator of the metabolic demands (Hall, 2015). Heart rate belts and watches were used to monitor HR (Polar V800, Oulu, Finland).

RPE, to assess athlete's perception of fatigue, was likewise recorded, as it can be considered a good indicator of global internal load when used with trained athletes (Impellizzeri et al. 2004; Wallace, Slattery and Coutts 2009).

Reaction time (RT) is essential to achieve success in motorsports (Baur et al. 2006), and almost all stimuli are visual. According to Baur et al. (2006) motorsport athletes have lower reaction times, compared to healthy individuals. In the review by Kosinski (1980), fatigue is presented as a factor that affects negatively RT. On the other hand, Collardeau and Alter (2001) found improvements in RT after a 40 minutes run. Also, low intensity exercise has been shown to affect positively RT tests (Behm et al. 2004). Reaction time may be a key factor in order to avoid injury, since motocross racing is a high-risk sport (Daniels et al. 2015).

A reaction time test was used, where subjects had to react to visual stimuli and press a button when the light turns on. The time until the subject pressed the button was recorded (Department of Biology of Physical Activity of the Jyväskylä University, Finland). Every subject spent 5 minutes familiarizing with the equipment prior the testing started.

Biomarkers of muscle damage and inflammation such as creatine kinase (CK) was analysed. CK is an accepted biomarker of muscle injury (Totsuka et al. 2002), but other studies showed no correlation between CK level and force decreases (Newham et al. 1987). Increases in CK serum can be caused from both metabolic and mechanical causes (Brancaccio et al. 2007). According to Warren et al. (1999) blood markers of muscle damage do not accurately reflect the actual state of the musculature, and they suggest the maximal voluntary contraction may be a better indicator of muscle damage. In line with the current literature, fingertip blood samples (samples stored at +4ºC for less than a day, and analysed with Konelab 20 XTi,Thermo Fisher Scientific, Vantaa, Finland) and strength tests were performed 24h after the simulated motocross race.

According to Knoblauch et al. (2010) fingertip blood samples are a valid system to measure CK blood level. The strength tests were the same as used during the simulated race day (HS, UBP and CMJ).

6.4 Data collection schedule

Testing took place during early autumn 2016 in Finland with Finnish racers competing in Finnish Championship, and recreational riders. The different recovery protocols were tested in different days, in the same racetrack, and with similar conditions (ambient conditions ±5ºC, and track conditions). Two recovery protocols were evaluated in 2 different days, trying to emulate as close as possible a race-day schedule (Table 5). Pre and post tests were implemented immediately before and after the races. Subjects assigned to active recovery protocol, started pedalling on the stationary bikes right after the performance tests were conducted. The active recovery protocol consisted of 20 minutes pedalling at 70% of the theoretical heart rate maximum of every subject.

TABLE 5. Testing schedule.

Pre Test	**1st Mx Bout**	**Post Test**	**Recovery Protocol**	**2nd Pre test**	**2nd Mx Bout**	**Post test**	**Post 24h test**
ST Power Lactate RPE RT	30’ Lap times control	ST Power Lactate RPE RT	Active or passive + Sports drink	ST Power Lactate RPE RT	30’ Lap times control	ST Power Lactate RPE RT	Blood sample + MVC

Before the pre-tests, all the participants performed a 10 minutes warm up on their motorcycles to increase body temperature and inspect the race track conditions. Also to emulate a race day schedule where racers have practice before the races start.

6.5 Statistical analyses

Data is presented as means and standard deviation (SD). Two-sample unequal variances t-test and paired sample t-tests were used to compare data obtained pre and post race and examine statistical significances. Correlation coefficient tests were used to find statistical relationships between two values. The value of significance used was $p<0.05$.

7 RESULTS

7.1 Lap times

No significant differences (p>0.8) or improvements were found when comparing differences between race 1 and race 2 lap-times when using either active and passive recovery protocols (Figure 3).

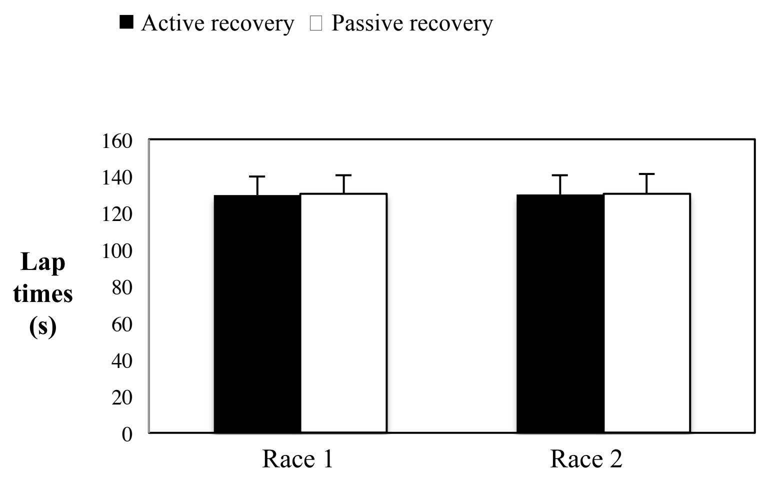
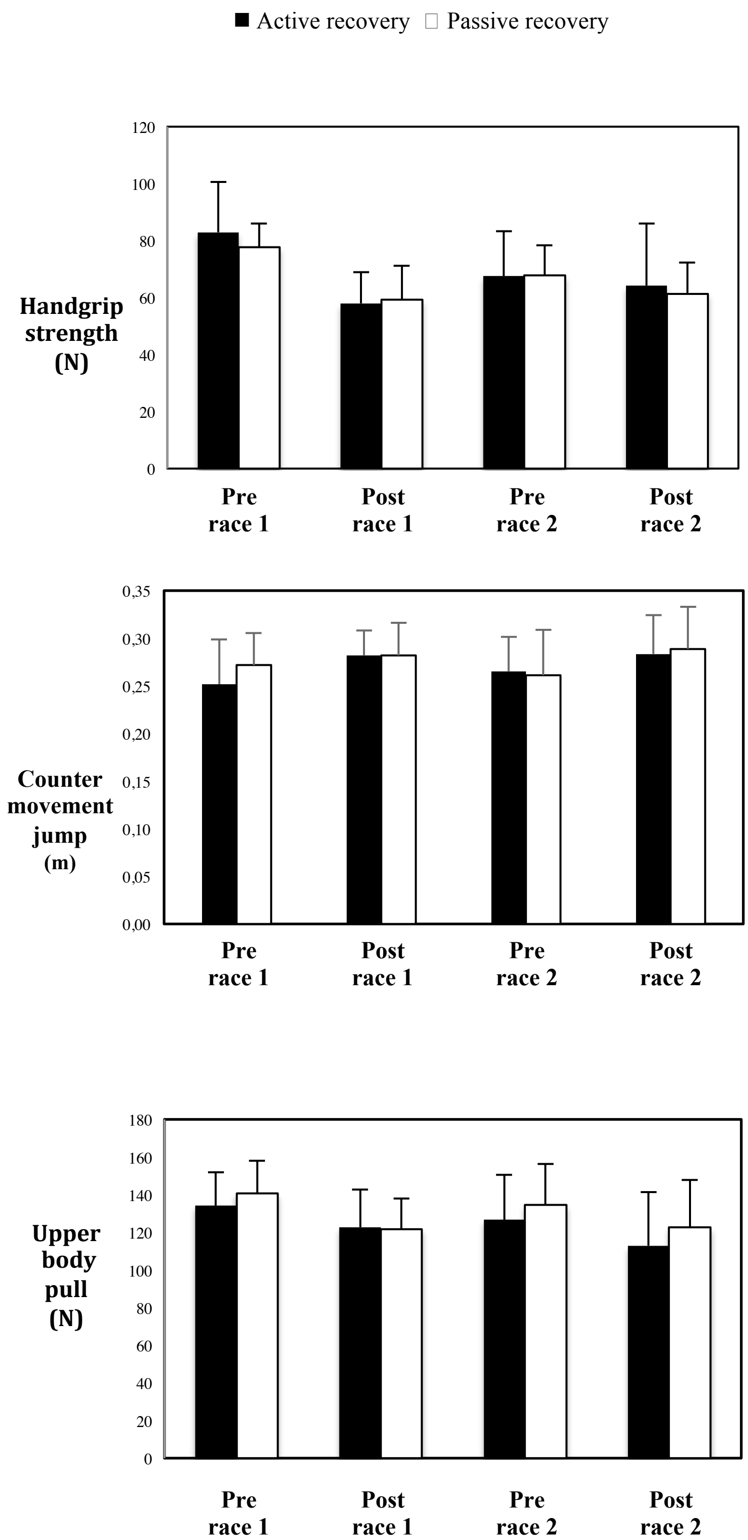


FIGURE 3. No significant differences between recovery protocols on LT.

7.2 Changes in force and power production

There were no differences in force and power production, when comparing active and passive recovery protocols in between races (CMJ p>0.1; UBP p>0.5; HS p>0.2; BT p>0.8). In force and power production active recovery does not look superior to passive recovery protocols between motocross bouts (figure 4).



■ Active recovery □ Passive recovery
Handgrip strength (N)
120
100
80
60
40
20
0
Pre race 1
Post race 1
Pre race 2
Post race 2
Counter movement jump (m)
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
Pre race 1
Post race 1
Pre race 2
Post race 2
Upper body pull (N)
180
160
140
120
100
80
60
40
20
0
Pre race 1
Post race 1
Pre race 2
Post race 2

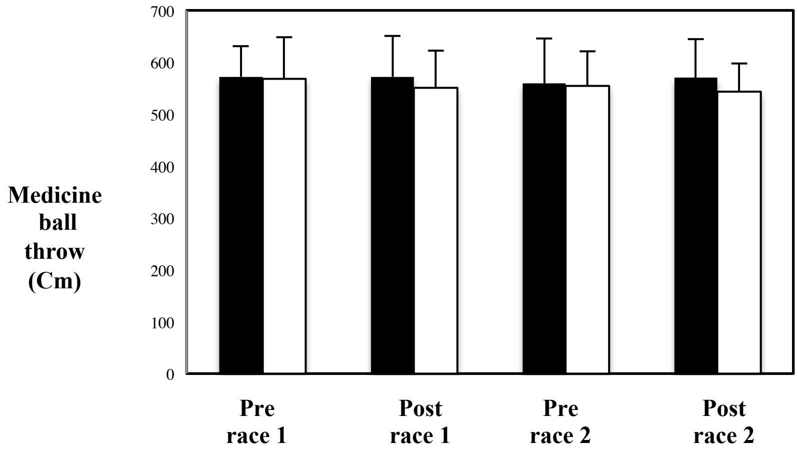


FIGURE 4. No significant differences between active and passive recovery protocols were found on force and power tests.

The different recovery protocols did not affect strength loses, but when comparing pre and post race handgrip strength values (figure 5), a significant decrease after race 1 can be recognized (p<0.001).

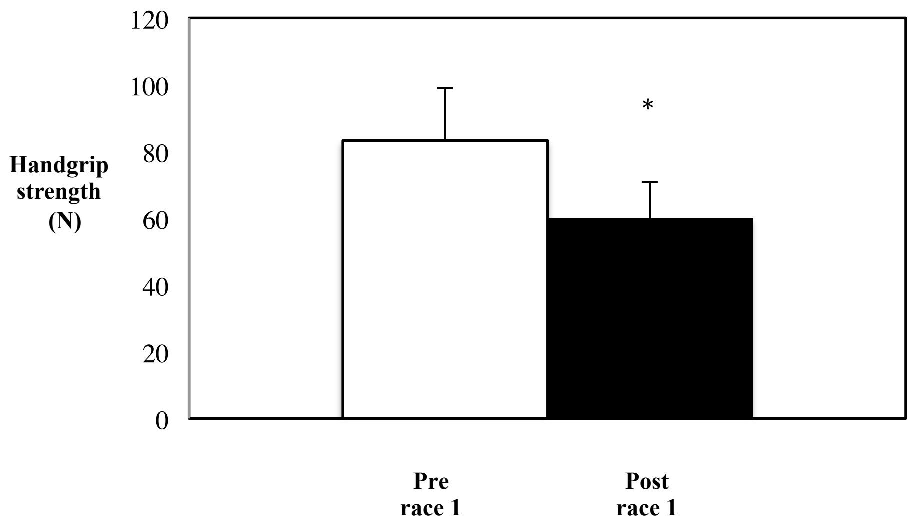


FIGURE 5. Pre and post race 1 handgrip strength levels. Significant decreases in handgrip strength when comparing pre race 1 to post race 1 results.

7.3. Physiological responses

The values measured during the simulated races are presented in figure 6. No differences in BL or HR (BL p>0.7; HR p>0.8) were found, when subjects performed active or passive recovery. The physiological responses stayed similar when using either active or passive recovery in between motocross bouts.

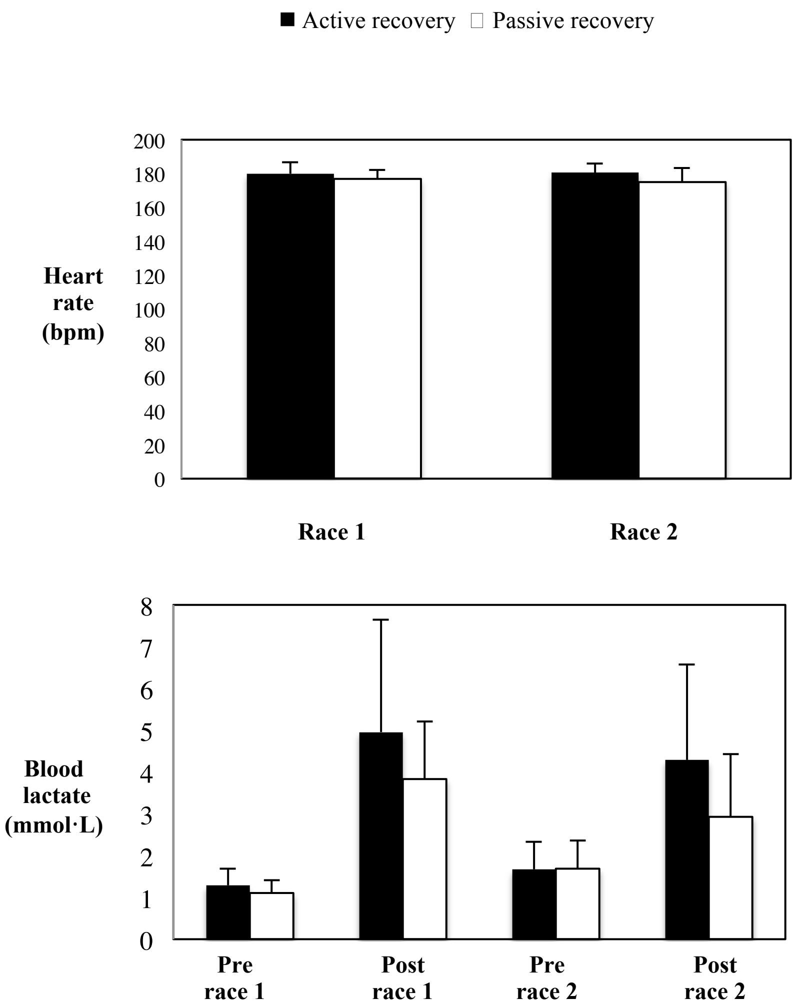


FIGURE 6. No significant differences were detected between active and passive recovery protocols on HR and BL.

As it can be seen in the BL figure, after passive recovery protocol, blood lactate post race tended to be lower, but like it was previously mentioned, this small difference was not significant. Values after the active recovery protocol (pre race 2) were not different.

As figure 7 shows, a significant increase ($p<0.001$) in BL was found when pre and post race 1 values are compared. There is an increase in BL during race 2, but the difference between pre and post is not significant.

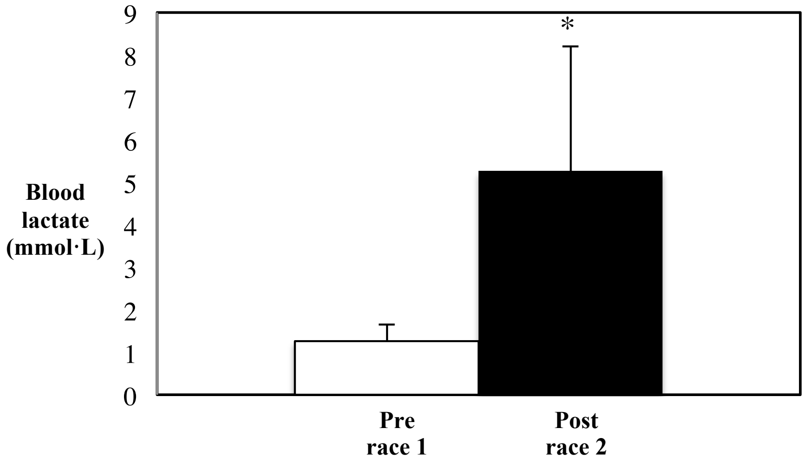


FIGURE 7. Pre and post race 1 blood lactate values.

7.4 Reaction time

Before the testing, all the participants spent 5 minutes getting familiar with the reaction time device to try to avoid learning effects. Active recovery did not seem to be superior compared to passive recovery, as there were no significant differences (RT $p>0.18$) between the two recovery protocols (figure 8).

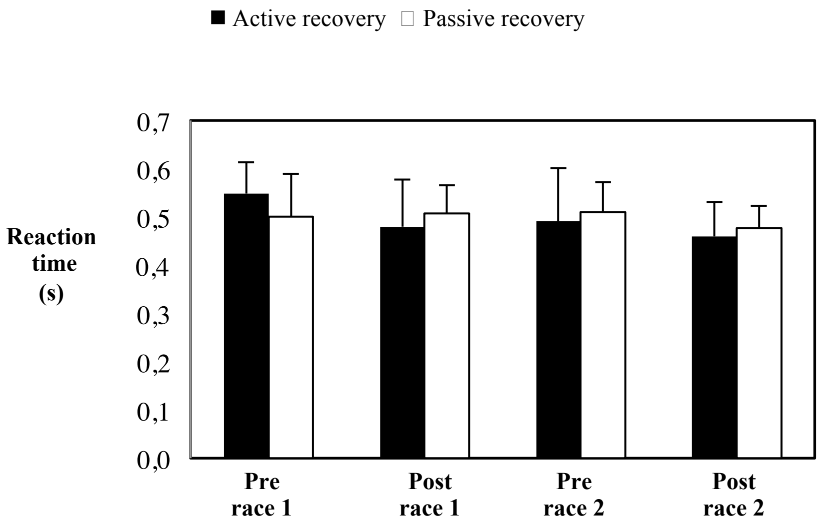


FIGURE 8. No differences were found when using active or passive recovery protocols between motocross races on RT.

Times tended to decrease as the tests went on, probably because of a learning effect. Participants learnt more every time they performed the test. This could have been avoided by having more familiarization sessions before the testing days.

7.5 Creatine kinase and strength tests 24h post race

Fingertip blood samples were obtained from all the subjects' 24h after the simulated motocross races. At the same time, all the participants performed strength tests (UBP, HS and CMJ), to see if there were any correlations between strength levels and CK levels that suggested muscle damage occur after motocross racing.

None of the recovery protocols seems to be superior, as no significant differences were found when analysing CK values. Results from CK are presented in figure 9. The strength and power tests do no present any significant differences when comparing active or passive recovery (Figure 10).

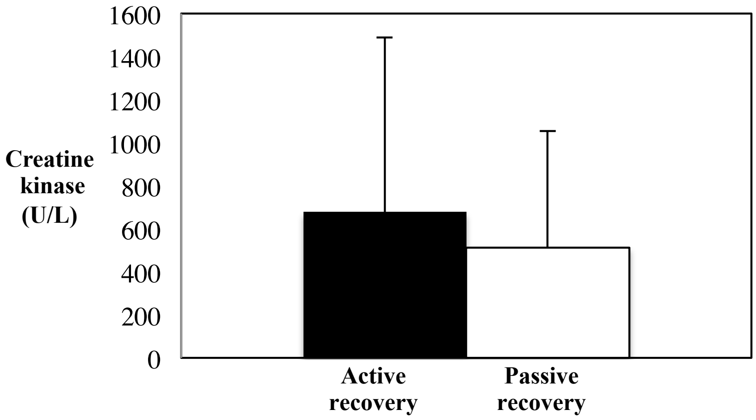
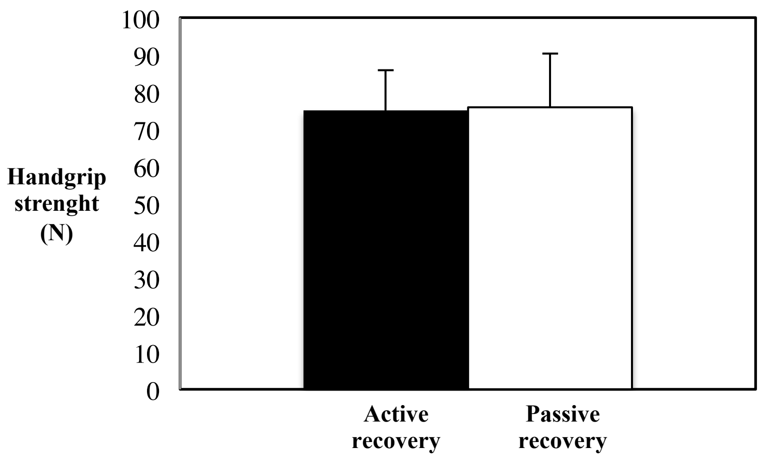
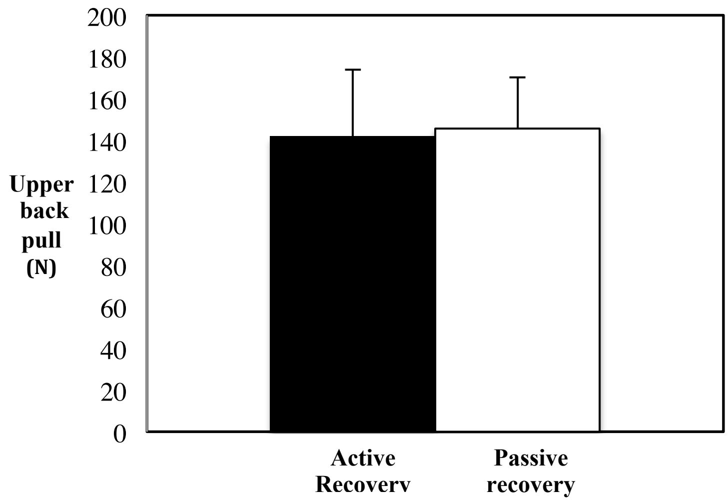


FIGURE 9. No significant differences between active or passive recovery protocols on CK values.





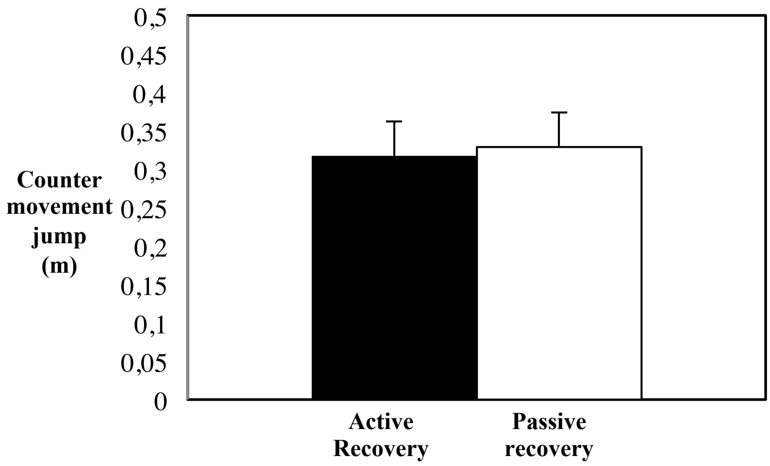


FIGURE 10. When analysing the data obtained 24h post racing, no significant differences were found between active and passive recovery.

On the other hand, even if the different recovery protocols did not bring any benefits when the strength tests were performed 1 day after a motocross race, the results from the study do show a decline in handgrip strength 24 hours post racing (HS $p<0.001$), when compared to baseline values.

8 DISCUSSION

Data obtained in this study suggest that active recovery in between motocross races does not increase specific motocross performance, neither strength, power or reaction time. Also, none of the recovery protocols had a positive effect reducing biological markers of muscle damage such as CK.

The results of the different tests performed during the simulated motocross races show decreases in strength, but not in power, and significant increases in BL after racing. These results correlate with some of the literature that has investigated this motorsport (Ascensão et al. 2007; Ascensão et al. 2008; Konttinen et al. 2007; Konttinen et al. 2008). Most of the participants improved their results in the CMJ test after racing, even tough this increase was not significant. According to Konttinen et al. (2008), EMG activity of the lower body during racing is between 30% and 45% of maximal voluntary contraction, it may be hypothesized that motocross racing may have some potentiation effect on the lower limbs that helps increase the results in power tests. When performing exercises with moderate intensities (60-84% of 1RM) increases in power output are found after some minutes of rest (Wilson et al. 2013). If the ratio between fatigue and potentiation is favourable to potentiation, power will be increased after performing moderate intensities movements (Wilson et al. 2013). It is possible that lower limb muscle actions during motocross can enhance power in a CMJ test just after racing. Another reason why the subjects performed higher CMJ could be because of the increase in temperature of the boots and knee braces materials, so the deformation of these protection accessories was easier, and the subjects found less resistance when jumping.

As hypothesized, active recovery was not superior to passive recovery when comparing performance values. The break between races was probably too long (1 hour) to enhance performance, as some of the literature suggests (Tessitore et al. 2007). It seems that active recovery might be beneficial when anaerobic contribution is considerable

(Franchini et al. 2009; Franchini et al. 2003), as it might help recover homeostasis and improve subsequent performance in the next exercise bout. Motocross racing is predominantly aerobic exercise (Konttinen et al. 2007), and probably that is one of the reasons why active recovery might not help increase performance in the second race. Also, active recovery seems to be superior when short periods of time are placed in between high intensity exercise (Franchini et al. 2009; Franchini et al. 2003), and the break in between simulated races for this study was 1 hour, similar to what is normal during a race weekend. Possibly if the length of the breaks between races were shorter, active recovery could have been more meaningful, as literature shows benefits of using active recovery when exercise bouts are separated by just a few minutes (Franchini et al. 2009; Franchini et al. 2003; Heyman et al. 2009). Short breaks in between races never happen at high level of racing, so doing a study with short breaks would have not been relevant to the sport needs. Likewise, active recovery can harm muscle glycogen resynthesis and thus subsequent performance when implemented in between exercise bouts (Fairchild et al. 2003). In the present study, passive recovery did not harm performance outcomes of the participants. According to the results obtained, active recovery will not increase motocross performance but it will not harm racing performance either.

Reaction time is important in motorsports, as it can be essential for success and is a key factor in order to avoid injury while riding (Baur et al. 2006; Daniels et al. 2015). RT scores did not vary between active and passive recovery protocols, and even if it was not significant, the scores improved every time the participants performed the test. This improvement can be caused by the physical activity performed by the subjects when riding the motorcycle (Collardeau and Alter 2001), or just by a learning effect. As the day went on, participants had more and more time in front of the device to measure RT and most likely they all learnt how to perform better.

Regarding exercise induced muscle damage and indirect biological markers, active recovery in between motocross races did not have a significant effect decreasing muscle damage. These results do not correlate with the data that Gill et al. (2006) presented in their study using male rugby players as subjects, where they found lower CK values when active recovery was used. The present results go in hand with the data collected in other scientific papers (Andersson et al. 2008; Wigernaes et al. 2000), in which the participants that performed active recovery after the exercise bouts did not show lower CK values compared to the other groups. The hypothesis of the study has been confirmed once again, as the use of active recovery does not seem to accelerate muscle damage recovery, but does not seem to harm recovery as well. In high competitive sports subjective feeling of readiness might be important, so coaches and athletes could use active recovery if the perception of readiness is higher.

This is the first study that assessed indirect markers of muscle damage after motocross racing. Fingertip blood tests to measure CK and strength tests were performed 24 hours after the simulated motocross race. CK values obtained 24 hours post racing were significantly high (678.67 u/L, SD = 810.5 u/L) compared to what is considered resting values (60-174 u/L) (Golan et al. 2011). According to (Mougios et al. 2007) athletes present higher resting CK values when compared to active subjects, however, in this study almost all of the participants cannot be considered high level racers. Strength values did not recover the baseline results obtained before racing, suggesting that there are decreases in strength after racing, for at least 24 hours. Warren et al. (1999) suggest that CK alone is not a good method to monitor muscle damage, but strength tests might provide more relevant information. With the results obtained, it seems that after motocross racing muscle damage may exists in non-elite racers. It is not surprising that the biggest decreases in strength were found when the finger flexors were tested, as Konttinen et al. (2008) reported that the finger flexors muscle group achieved the highest EMG values while riding, and eccentric muscle actions are usual during motocross racing (Konttinen et al. 2008). Marina et al. (2011) found reductions in finger flexors strength after racing in road motorcycling athletes as well, and the demands of on road motorcycling are probably lower than in motocross because of the even racing surface. Repeated bout effect should be contemplated (Brown et al. 1997), as if the participants of the study were used to do two 30 minutes races every week, the degree of muscle damage would have been probably minimal. Coaches should consider this information, as well as the level of the racers, when planning a training program after a race weekend, as Avela et al. (1999) showed that after exercise induced muscle damage, the human body might need several days to recover homeostasis.

To our knowledge, this is the first study that analysed the effects of different recovery protocols during a motocross race, and also the only one to assess muscle damage post motocross riding. The data obtained bring some more light about the demands and the impact that motocross racing has on the human body. Previous research has always used practice sessions to measure the toll that motocross has on the system, while in the actual paper, a simulated race with a real start was performed and the times obtained by every participant during the whole race were recorded, as this is the most important variable while racing bikes on a circuit, and it is as well the most specific test that can be run to measure performance.

The level of the participants as well as the recovery protocol chosen can be considered as a limitation of this study. The results obtained could have been more relevant if the participants were high-level riders. Almost all of the subjects involved in this research were hobby racers, except two, that were top racers in Finland. Future research should try and test athletes during a real race. Even tough participants were encouraged to give their best at all times, the intensity of a practice day can never match a real race.

The active recovery protocol chosen was similar to the one used by Heyman et al. (2009), where they had rock climbers as participants, and cycled at low levels of power for 20 minutes. Finger flexors endurance is high in rock climbers (MacLeod et al. 2007), and the activation of the finger flexors can be considered to be similar to motocross racing. In the present study, the intensity and the length of the protocol chosen could have been not ideal to see any changes in performance. It seems that there is a consensus on the literature about the optimal intensity to enhance lactate removal, but there is not an agreement on which active recovery protocol is the ideal to bring positive changes in performance after a sport event. All the studies in the field choose different intensities, different lengths and different types of exercise, which makes it hard for future research to be relevant. Also, every sport is different and depending on the intensity and the length of the sport bout one protocol could be superior to another.

9 CONCLUSIONS

In conclusion, active recovery does not seem to enhance riding performance neither strength, power and reaction time. It seems that some degree of muscle damage after a simulated motocross race exists, but this muscle damage it is not affected by the use of active or passive recovery in between races. Coaches and athletes can use active recovery in between races if subjective perception of recovery is higher, as performance will not be harmed. Also, it should be kept in mind that muscle damage exists after racing. Therefore a rest period would be necessary after a race weekend in order to recover baseline levels. Isometric maximal voluntary contractions could be an easy and quick tool to assess fitness state of the athletes after a race, as blood tests to measure biological markers of exercise induced muscle damage are expensive and difficult to implement with athletes.

10 PRACTICAL APPLICATIONS

With the present findings, coaches and athletes may take into consideration that motocross performance will not increase if light exercise is completed between race breaks. On the other hand performance in the motocross track will not be hurt if some kind of undemanding physical activity is carried in between races. Motocross racing decreases physical capacities such as strength for at least 24 hours, so some recovery time may be needed to fully recover. Rest periods after a race weekend and the addition or not of active recovery in between races should be individualized, as some athletes may benefit from it and some others may not.

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