Bachelor Thesis

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[The effect of back extensor muscle fatigue on dynamic motor control, after a drop jump]

Preface

Since childhood, sport has always been an important part of my life; as an athlete as well as a coach. As a result, I developed the motivation to study physiotherapy and to choose this topic as my graduation work.

To Verena Mitterer, Nicholas Quinn, Maximillian Vitelleschi-Cook and Tombra Abeke who provided useful feedback. I would like to express my sincerest thanks to them. I would also like to thank Leonie von Hagen for repeated proofreading and for giving me a push, when I needed it.

1. ABSTRACT

Introduction: In recent years some researchers investigated the effect of lumbar muscle fatigue on postural control in quiet standing and sitting. The goal of this study was to transfer the question if changes in postural control are visible after fatigue into a functional, dynamic setting.

Research question: Does muscular exhaustion of the back extensor musculature have an effect on dynamic motor control, after a drop jump?

Method: Twenty young healthy students, ten female and ten male, were asked to perform drop jumps from a 25 cm high platform. Ten jumps were recorded in total, five jumps in fatigued and five in an unfatigued state. The intervention exercise consisted of back extensions on a 45° inclined treatment bench until maximal exhaustion was achieved and aimed for at lumbar back extensor muscle fatigue. Each measurement lasted exactly 5 seconds per drop jump, starting with establishing ground contact. Centre of pressure displacement was recorded using a force plate. This output was processed via space time analyses using Codamotion software.

Results: Significant effect was found in anterior-posterior sway after the fatiguing exercise. No effect in medial-lateral sway was observed. Investigating only the first 2,5 seconds separately gives the same result. No significant results were found in anterior-posterior and medial-lateral direction in the last 2,5 second interval.

Conclusion: The findings of this study show a direct relation between lumbar extensor muscle fatigue and postural control in anterior-posterior direction in a dynamic, functional setting. Neuromuscular changes due to fatigue are likely to be the cause for increased sway. Results appear to cohere with previous research assessing sway in static situations.

Key words: sway, drop jump, fatigue, back extensor muscles, centre of pressure

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2. INTRODUCTION

Core stability has become an important topic in the field of physiotherapy in the recent years. It is the body's ability to control its position in space against disturbances (Zazulak et al., 2007). By that it provides the base for postural control.

Core stability comprises of active and passive structures such as ligaments, capsules and intervertebral discs. The passive stability is enhanced by the active stability provided by muscles, such as the trunk musculature (Cholewicki et al., 1997). The sensori-motor process of postural control (Schmidt et al., 1975) receives input from the active and passive systems, and is processed by the nervous system. Joint and muscle proprioceptors cooperate with the visual and vestibular system in a reflexive feedback loop in order to coordinate the position of the body (Moorhouse and Granata, 2007).

In order to be able to stabilize the spine and counteract the torques created by the limbs, interplay between passive and active structures is necessary. If the spine cannot absorb the external forces, a reaction of the distal joints of the kinetic chain becomes necessary, like a control step. Consequently, external forces that are compensated in the lumbar spine do not compel action of the e.g. the knee joint. This stability may reduce the risk of injury in the lower limb. Research by Zazulak et al. (2007) has shown a higher risk of knee injury in young female football players who had bad proprioceptive trunk repositioning ability.

Due to the belief that core stability and injury prevention are interrelated, core stability found its way into a variety of training programs including sport and rehabilitation for a variety of patient categories (Borghuis et al., 2008).

There is some evidence that athletes with low core stability have a higher chance of injury in the lower limb and back (Cholewicki et al., 2005; Zazulak et al., 2007). Both assessed muscle reflex latencies by measuring trunk displacement after a sudden force release in extension, flexion and side flexion. Furthermore there is some evidence supporting a correlation between core stability and performance in football players (Nesser et al., 2008).

Fatigue is known to have impact on muscles by reducing maximum force and to adversely affect proprioception (Taimela et al., 2009). Taking the importance of reflexive muscle activity for stability into account a negative effect on core stability can be expected from fatigue (Taimela et al., 2009).

Localized muscle fatigue has been shown to increase postural sway in quiet standing and therefor contributing to a higher risk of falling. Lepers et al. (1997) found restricted balance after cardiovascular and lower extremity fatigue induced by running and cycling. Other authors reported similar effects after fatiguing the ankle musculature (Johnston et al., 1998) as well as after localized shoulder fatigue caused by longer overhead work (Nussbaum, 2003) or neck fatigue (Schieppati et al., 2003).

Earlier studies investigated the effect of fatigued back extensor muscles that were fatigued on 60 per cent of their original power (Davidson et al., 2004, 2009). They found an impairment of balance control in standing still on a force plate, with feet together, after performing back extensions on a roman chair. According to Granata and Gottipati (2008) extensor fatigue has a negative effect on local trunk stability and therefore may contribute to lower back injuries. They compared the change via mathematical equations in unfatigued and 60 per cent of original power fatigued state. A study by Wilson et al. (2006) assessed the effect of extensor fatigue on postural strategies after balance perturbations with a pendulum. After fatiguing, they found an altered sway and correlated this to a changed posture (changed postural strategy). Davidson et al. (2004) found increased postural sway after lumbar extensor fatigue in quiet standing.

Lumbar muscle fatigue frequently occurs in occupational lifting tasks, sports such as dancing, football, hockey, tennis, volleyball, badminton, athletics and so forth. This is why the lumbar extensors are of special interest for this study. Previous studies, as named above, examined the trunk stability in quiet standing or sitting, which are not frequent actions during earlier mentioned activities, in which core stability is so important. Dynamic motor control is possibly more related to functional daily activities compared to previously investigated static control, and might have more relevance in injury prevention. Given the more complex task, it is not known yet, if the effects of fatigue are similar to quiet standing, or even enhanced. This raises the question how one could measure dynamic postural control in a functional, global way, which is closely related to every day and sport activities.

Midstance position is one of the phases of the gait and running cycle. It is a phase of single leg-support, when the weight of the body is propelled forward over the foot. During this phase the individual has to stabilize her/his body in space, against its own weight and external forces. The drop jump and landing position appears to sufficiently mirror this phase and therefore seems to be a functional approach. By comparing this moment in fatigued and unfatigued state, this study is expected to provide information that is directly applicable on training and rehab programs. Information collected in this moment in this phase is expected among other things to enable the physiotherapist or coach to specifically train somebody in the state of fatigue. Training with high load intensity can be desired in athlete training as well as in patients with increased lower extremity injury sensitivity or involvement to injury prevention (Zazulak et al., 2007). But it also can be used to familiarize the athlete or client with effect fatigue has on the body. With this, an individual bearing strategy and training plan can be developed specifically tuned on the individual requirements.
Subsequently, the aim of this study is to assess the effects of fatigue on stability in a very frequent occurring dynamic situation. It is expected that postural control is decreasing in fatigued state, which leads to the research question: Does muscular exhaustion of the back musculature have an effect on postural control, after a drop jump?

3. METHOD

In this randomized controlled crossover study, 20 subjects (10 females and 10 males) were tested on sway after performing a single leg drop jump. The measured time sequence was the five second interval beginning with impact after dropping from 25 cm high starting platform. Subjects performed two sets of five drop jumps onto a force plate, one set with a fatiguing intervention immediately before and one set in a rested state. The variables examined in this study were sway on a force plate in time. Data from the force plate (AMTI OR6-7, USA) were recorded at 1000 hertz (Hz). The measured sequence began with established ground contact. The sway was measured in millimeter (mm) in all horizontal directions, where the x-axis indicates anterior-posterior (AP) sway and the y-axis indicates medial-lateral (ML) sway. This becomes visible via Centre of Pressure (CoP) measurement carried out by the force plate and recorded in the Codamotion Analyses computer program. Salavati et al. (2009) has shown a high reliability of standard deviation measurements as an indicator for sway.

All participants were recruited and briefed, at a later stage, with an informational letter (appendix 1) via email. Twenty young, healthy and sportive adults decided voluntarily to take part in this experiment. Lower limb or back injuries in the past year were exclusion criteria, as well as neurological pathologies or vestibular dysfunctions. All subjects were informed about possible risks and signed a letter of informed consent (appendix 2) prior to the testing procedure. The research topic was approved by the local ethics committee of the Maxima Medical Centre. They considered the research not to be a medical research in terms of the WMO (Medical Scientific Research Law). Further approval was given via the acceptance of the project plan (appendix 3). The collected data were only accessible to the responsible persons of the research and were kept anonymous. The involved data and the intellectual property rights and claims were handed over to Fontys University of Applied Sciences (appendix 4), who committed itself to a confidentiality statement (appendix 5).

Subjects	**1st Test**	**2nd Test**
Subject 1	Fatigued	Not Fatigued
	Seated Balance (SB) Single Leg Drop (SLD)	SB SLD
Subject 2	Not Fatigued	Fatigued
	SLD SB	SLD SB
Subject 3	Fatigued	Not Fatigued
	SB SLD	SB SLD
Subject 4	Not Fatigued	Fatigued
	SLD SB	SLD SB

Figure 1, randomized crossover testing
SLD = Single Leg Drop Jump
SB = Seated Balance Test, only relevant for co-researcher

3.1. EXPERIMENTAL PROTOCOL

The testing protocol (Figure 1) was designed as a cooperation study, where the other study aimed on seated balance performance influenced by the same intervention. The same intervention exercise and two non-interfering test procedures were scheduled in a complete randomized order. To achieve randomization, half of the subjects (5 females and 5 males) were chosen coincidental and without any criteria to start in fatigued state, while the other half (again 5 females and 5 males) started in coincidental order in unfatigued state. Randomization was achieved by creating a time schedule with blank slots, where the concrete subjects were placed in by drawing lots. The chosen intervention was a back extension exercise on a 45° inclined treatment bench as illustrated in Figure 2, until full exhaustion. This was achieved when the subject was unable to perform another repetition, or compensation, defined as a rolling upward movement in the spine instead of smooth extension in the lumbar spine. This was observed by the fixating researcher.

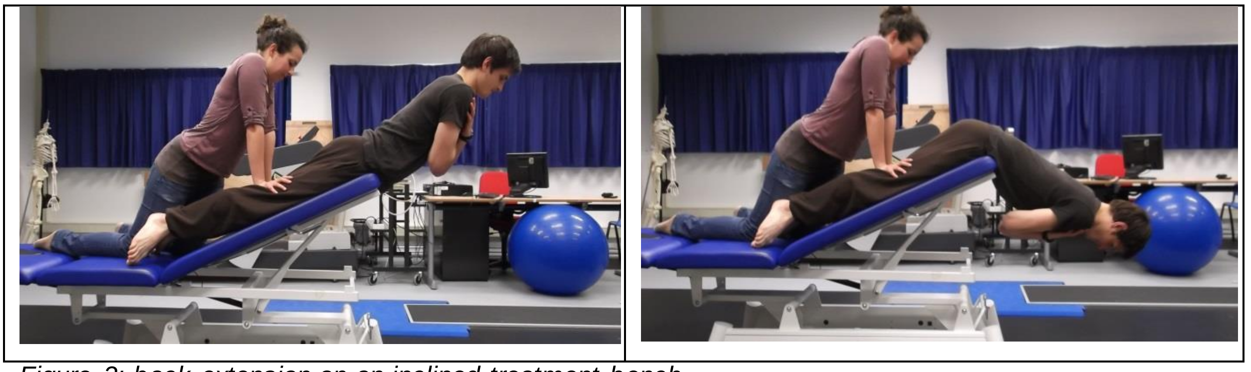

Figure 2: back extension on an inclined treatment bench

The experimental set-up for this study was a 25 cm high starting block placed 1 cm in front of the plate. Every single leg drop jump started with the command "go" when the force plate was active and recording, immediately followed by the drop. For data analysis, the first five seconds beginning with established ground contact were used only. The subject's initial starting position was on the platform with his dominant leg while the other leg was flexed at 90° in the hip and knee joints. The hands were resting on the hip bones and the ankle joint was in a neutral position. The correct starting position was held for 1 second, to ensure same starting conditions for all subjects. After landing, the body had to be held in a stabile position without touching the ground with the opposing leg for 5 seconds of recording time, on the force plate. This procedure was recorded 5 times each, for both rested and fatigued condition. Drop jumps not meeting the mentioned criteria where repeated.

Figure 3, Single leg drop jump, 1) start position 2) drop 3) landing phase 4) balancing till 5 second signal

Before starting the actual testing protocol, subjects were familiarized with the testing tools and the drop jump by performing several test jumps. Due to these repetitions on forehand a learning effect during the recorded trials was inhibited. In this introduction phase, the subject performed six trials. As soon as the subject felt comfortable with the performance of the exercise, he had to perform three successful trials under supervision of the examiner. These were defined as, a proper dropping down from the 25 cm block, without jumping in a matter that would gain more height than necessary to leave the start box, with the dominant leg as shown in Figure 3. After landing, the subject's foot had to "stick" (no replacing or double hop with the foot) to the force plate for at least 5 seconds without touching the ground with the opposing leg.
All subjects were asked to avoid sport in the 12 hours before the testing, to avoid negative effects of workouts such as muscle fatigue.

3.2. DATA ANALYSIS

The force platform recorded the displacement of the CoP, and provided x and y values every 0,001 seconds (1000Hz). These measured movements illustrate sway of the subjects' body, and made changes calculable. Figure 4 shows a typical example of a five seconds trajectory.

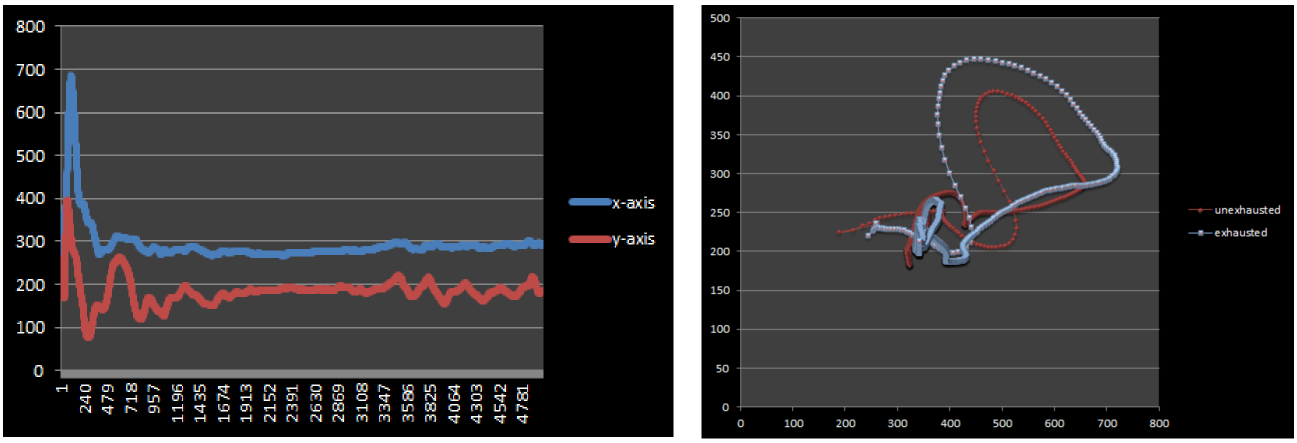

Figure 4, left: Amplitude of anterior-posterior (blue) and medial-lateral (red); right: trajectory CoP single leg drop jump in fatigued (blue) and unfatigued (red) state (right dominant leg).

From this data the following seven variables were calculated with Excel, Microsoft Office 2010: standard deviation of x and y value, standard deviation of the vector and the mean velocity of x and y. Additionally, the standard deviation of x and y in the first and last 2,5 seconds of the interval were calculated separately in order analyze the impact phase separated as well as to get an impression of the balancing phase after the impact. By calculating the average of the five jumps in both states of all variables, the data was modified for statistical analyze. In this step, SPSS (Version 18, PASW Predictive Analyze Software) was used. The individual mean scores for exhausted and unexhausted were calculated and compared via Wilcoxon two paired sample test. A *p*-value of 0,05 or lower was considered as statistical significant.

4. RESULTS

None of the participants had to be excluded, therefore the outcome of this research is based on a sample size of 20 subjects, 10 female and 10 male. The subjects mean (±standard deviation) of age, height and weight was 23,75 (±2,45) years of age, 177,3 (±9,39) centimeter and 70,38 (±12,32) kilograms. All subjects were sportive students, with at least 2 sport sessions per week and 3 hours of sport per week in total.

Figure 4 (left) shows a representative amplitude in AP direction (x-axis) and ML (y-axis), where the first peak marks the impact after dropping. The picture on the right (Figure 4) presents two drop jumps of the same subject, once in a fatigued and once in an unfatigued condition. It represents trajectories of subject’s dominant right leg. A left leg dominant subject will present a similar shape but mirrored trajectories.

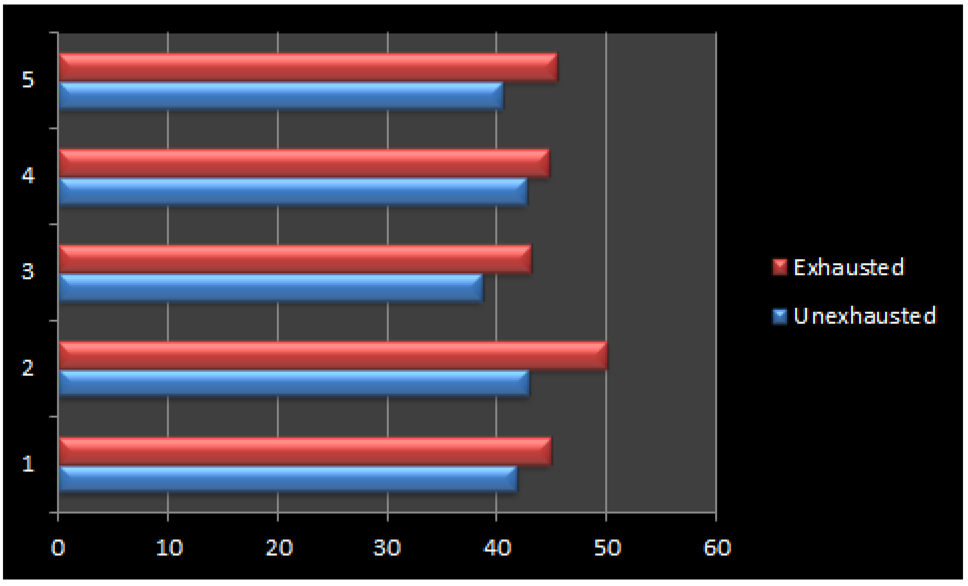

Figure 5: comparison of sway in anterior-posterior direction, 1 subject, twice 5 jumps in each state

Figure 5 presents the comparison between the unfatigued testing and the fatigued testing in the 5 second interval of the same subject in AP direction. An overview over all relevant *p*-values can be found in Table 2. A significant effect (p = 0,008) was shown for sway in AP direction (x-axis). Whereas no effect (p = 0,940) was shown ML direction (y-axis). The vector shows significant results (p = 0,015). No significant effect can be reported in mean velocity of x (p = 0,218) and y (p = 0,627). Also see Table 2 for more information.

Table 1: Overview p-values, Medians (mm) and inter quartile Ranges of 25 % and 75 % in fatigued and unfatigued state

		Fatigued			**Unfatigued**		
	P value	Median	IQR25%	IQR75%	Median	IQR25%	IQR75%
Sway AP	,008	44,740	40,332	52,106	43,557	40,701	48,077
Sway ML	,940	18,062	16,474	22,646	19,299	15,566	22,489
Vector	,015	41,805	37,704	47,939	41,464	35,487	44,277
Velocity AP	,218	326,206	288,486	364,108	317,293	285,338	350,951
Velocity ML	,627	263,316	221,863	283,813	245,691	222,487	279,536
0,0-2,5 sway AP	,030	62,028	54,699	71,119	59,993	56,800	66,009
0,0-2,5 sway ML	,627	24,538	21,946	29,262	26,267	20,022	30,622
2,5-5,0 sway AP	,351	4,335	3,150	5,390	4,145	2,979	4,973
2,5-5,0 sway ML	,057	5,008	4,208	6,800	4,416	3,646	5,628

IQR = Inter quartile Range
AP = anterior-posterior
ML = medial-lateral

As presented in Table 1, first and second half of the five second interval has been analyzed separately. Looking on the x-axis, the significance effect in the first half (*p* = 0,030) remains significant, but not in the second half (*p* = 0,351). Looking at the y-axis, the in general insignificant effect is confirmed in the first 2,5 second interval (*p* = 0,627), but a trend becomes visible in the second half (*p* = 0,057).

The connected Median and inter quartile ranges are reported are reported in table 1 as well.

5. DISCUSSION

This study was designed to find out whether there is an influence of back extensor fatigue on dynamic motor control in a frequent, functional movement. As indicated in the result section, there is significant effect in AP direction concerning the full five second interval measurement - however no effect is shown in ML direction. The total sway (vector), a combination of both sway dimensions (AP and ML), has shown significant differences between fatigued and unfatigued state. However, this is not considered to be relevant for this study, due to entirely oppositional significances of each variable due to the high insignificant *p*-value of ML sway.

A possible approach to explain these results requires a closer look at the subjects' movements. Changes of the centre of mass (CoM) are possibly processed and counteracted slower and/or with less effect due to fatigue (Björklund et al., 2009). Increased changes of the CoM can be caused by altered functionality of the sensory proprioceptive and motor system (Vuillerme et al., 2007). According to Mirka and Black (2009) proprioceptive (somatosensory) system is one of three systems involved in balance control. The two others are the visual and vestibular systems, and are unlikely to be affected by the presented testing procedure.

Consequently, the idea of proprioceptive involvement arises and becomes more plausible by considering that the primary fatigued muscles, the back extensors, are mainly involved in AP movements. Also, the observed results show a bigger effect in AP direction than in ML direction. This line of reasoning is supported by previous research done by Taimela et al. (1999) which has shown that the ability of sensing lumbar position is impaired by fatigued trunk musculature, resulting in reduced muscular responses due to increased proprioceptive thresholds. More general, a negative effect of muscle fatigue on joint proprioception has been shown by Björklund et al. (2009). Wilder et al. (1996) has shown a delay of muscle reaction time after a sudden load in the fatigued state.

Not only input, the proprioception, is susceptible to disturbances due to fatigue but also the motor function output can be influenced. The underlying cause of altered muscle function after fatigue causing an increase in sway is explained by Missenard et al. (2009). They found that a fatigued agonistic muscle requires increased activation levels to maintain output force, which can result in unsteadiness of power output. This unsteadiness is an effect which can be increased if subjects stiffen up their spine in order to maintain stability. As a result of the muscle guarding by antagonistic co-contraction Selen et al. (2009) found an increase in muscle force variability.

Another possible explanation is reduced muscle force due to muscle fatigue leading to increased AP sway, which goes in line with the increase in sway found in this study. Maintaining posture requires accurate control movements of specific muscles rather than maximum forces of muscle groups. Cholewicki et al. (1996) stated that muscle activity of multifiduus and erector spinae muscle with 1-3 % of their maximum power is sufficient to restore stability. In their test build up lifting tasks in various positions were used in order to disturb balance, which can be considered as a comparable challenge to the drop jump. Consequently, an influence of reduced muscle force due to fatigue appears to be unlikely.

Fatigue leads to a higher breathing frequency and volume, which can also contribute to increased sway. This theory is supported by several previous studies such as Sakellari and Bronstein (1997). Respiration was not measured in the present study; however, small differences in respiration frequency were observed by the examiner. Davidson et al. (2004) addressed this issue by running a small test trial subordinated in his main study. They investigated if sway increases with increased respiration in the absence of lumbar extensor fatigue in the same way as with a combination of both. They further investigated to what amount their interventions raised the frequency. They concluded that the increased respiration did not contribute significantly to the sway measured. According to Jansen et al. (2010) a respiratory effect in sway will most likely affect medial-lateral sway, which supports the hypothesis of no respiratory effect in the present test build up.

Previous studies show a relative independence of CoP movements concerning directions. Rougier (2003) states that alterations in one movement direction do not necessarily result in an alteration in another direction.

In contrast, a similar study performed by Vuillerme et al. (2007) supports the outcome of increase AP sway after the fatiguing intervention of this study. They found larger variances on both axes, yet report the bigger effect in AP direction. The different outcome might be due to different choices in the build-up of the experiment. Vuillerme et al. (2007)'s measurement took place in undisturbed stance with closed eyes. Under normal circumstances, one has three systems involved in balance control: the vestibular system, proprioceptive system and visual system (Mirka and Black, 2009). One explanation by Vuillerme is, contrary to the findings of Rougier (2003), a possible connection between the two planes. Conducting an experiment investigating balance reactions, raises the question, how important each contributing system is for maintaining equilibrium. By excluding the visual system, the subject has to rely on his vestibular and proprioceptive system only, which is likely to be the reason for the different test result compared to the present one. For the present experiment, excluding a system was not the chosen approach, since most daily tasks are performed with open eyes.

The outcome of a study conducted by Van Dieen et al. (2011) indicates a transferability of findings between sway in sitting and standing. He investigated the effect of general fatigue in elite gymnasts by using a construction causing a sudden force release while being seated on a balance board. His intervention was chosen by putting together a ten minute protocol consisting of different typical tasks of a gymnastic training session. The outcome of their study is congruent with the present one. They report significant effect in AP direction after fatigue, while having no effect in ML direction in the same condition.

Furthermore, the method of this study at hand might enhance the clearer findings in AP direction, compared to the ML sway. Its buildup might force the subjects directly after performing a drop jump to counterbalance the frontward directed movement and could alter the subjects CoM in anterior direction. This asks neuromuscular activity to counteract this momentum in order to prevent falling forward (Vuillerme et al. 2007). This can explain the greater amplitudes in AP direction compared with the ML direction (Figure 4). It can also explain what causes the increased amount of sway in fatigued condition.

Johanson et al. (2011) investigated the effect of back muscle fatigue on postural control in quiet standing by applying muscle vibration devices on the triceps surae and lumbar multifidii muscles. During vibration the proprioception is changed by creating an illusion of muscle lengthening (Cordo et al., 2005). In line with the results of the present study, they observed an altered sway in AP direction.

Further investigation revealed that varying triceps surae proprioception results in posterior sway, while vibration on the multifidi muscles results in anterior sway. The data on hand confirms this initial anterior directed sway, but cannot be considered statistically relevant since the measured drop jump dictates a forward trajectory of the CoP. Furthermore Johanson et al. (2011) found out, that healthy subjects in fatigued state standing on a foamy surface were significantly more dependent on proprioception provided by the ankle. They suggest that a change of postural strategy from lumbar to ankle might be responsible for that. Following the kinetic chain, joints of the lower limb are now more dynamically involved in maintaining balance. This can lead to more instability of the whole system and may result in increased sway. According to Johanson et al. (2011), relying mainly on ankle proprioception reduces the ability to adapt to coordinatively more complex tasks. In a more complex task, the postural demands might increase to a point that the proprioceptive information is insufficient. This is simulated by the drop jump, which resulted in more sway.

The findings of this present study over the full 5 second time period, are also visible, looking on the first 2,5 seconds only. A significant effect in AP direction is observed, while ML sway remains unaffected. This changes in the last 2,5 seconds, where the sway in ML direction shows almost significant effect, contrarily to AP sway, which becomes insignificant in this last interval. The last 2,5 seconds are comparable with previous studies done by numerous authors named in the introduction. Their testing condition was a “standing still” condition. Since the balance disturbance of landing was equilibrated in most instances after 2,5 seconds, undisturbed stance experiments seem to be an appropriate comparison. Therefore the present results of the last interval are unexpected, since they do not confirm previous studies. For example, Vuillerme et al. (2004) found significant increase of AP sway in standing still. The reason for this is likely to be found in the different build ups, where contrary to this study, quiet two feet stance with closed eyes were assessed. There was no literature found about CoP trajectory in single leg stance, that could be used to compare the ML trend found in this study.

Subjects with a lower limb or back injury in the past year had to be excluded as well as subjects with a history of neurological pathology or vestibular dysfunction. Most of the articles and surveys referred to in this work, named similar in- and exclusion criteria. Furthermore, most of them worked with similar subject groups of young healthy adults performing sport activities on a regular basis. An exception was the work of van Dieen et al. (2011), who used female elite gymnasts for his seated balance experiment. Most of the studies do not name the ratio of female and male subjects, but no literature was found stating a gender difference.

5.1 STRENGTH

The study population can be considered as representative of a broad range of target groups. By assessing a young (mean age 23,75 years) and sportive group, who perform at least two sport sessions per week, the results of this study are applicable to subjects, where injury prevention, rehabilitation and correct training concepts are most utilized. Since it was a random student population, various sports were present from diving on national level, ambitious climbing and football to recreational running. Due to the fact that ten females and ten males were tested, the result can be considered as universally applicable. However, a different result could be observed when tested on one gender only. The specific test build up may not represent hundred per cent of an actual movement occurring in daily life or during sport. But to the authors knowledge there is no build up mentioned in literature that is closer to functional sport movements, then the present one. Full randomization of the test protocol plus a familiarizing before the actual test, minimized the likelihood of a learning effect.

5.2 LIMITATIONS

Even though the test build up was aimed at functionality, it is still an artificial test and therefore cannot mimic open nature movements. Furthermore a bigger sample size than the present 20 would allow stronger results and conclusions. However, previous authors also worked with small sample sizes, i.e. Vuillerme et al. (2007) worked with 12 subjects. Also the trend, but yet insignificant result of the ML sway in the last 2,5 second interval, might become clearer being tested in bigger sample sizes. Even though a randomization process and a familiarizing period were included, a learning effect can never fully be excluded.

Lastly, due to the double study build up, performing one intervention yet two different tests in each state, interference is likely. Every second test subject started in a state of fatigue, or rested respectively. For those subjects, who performed the fatigued testing first, a break of 15 minutes was scheduled. A remaining rest fatigue to a certain extent is possible, but a longer break was not chosen, in order to keep the total testing time acceptable for the subjects.

5.3 FUTURE RECOMMENDATIONS

Future research is indicated in order to find out the precise point when balance is established after a drop jump. Further studies can be used to find out whether this “finding phase” increases or not. Also, bigger sample sizes should be used, to examine the trend concerning ML sway in the second 2,5 second interval indicated in this study.

5.4 CLINICAL IMPLICATIONS

The results of this study suggest an increase in AP sway after lumbar back extensor fatigue. Increased sway can be seen as direct relation to an increased risk of injury as confirmed by Zazulak et al. (2007). This knowledge can be used in rehabilitation and injury prevention and is transferable in daily practice. Therapists can implement this knowledge into their training schedule, by specifically training ankle, knee and trunk stability in a state of fatigue. For example, one might create an intensive stimulus, such as sprints, followed by shooting practice in football (hockey, basketball, etc.) or difficult elements in the end of a gymnastic freestyle. In a rehabilitational setting, the ability to perform on highly demanding functional levels as named above must be re-established by less functional exercises. These can aim specifically at stability by training single leg squats after aerobic training with a focus on the mechanical leg axis. Professional sport as well as recreational athletes are addressed by these findings.

6. CONCLUSION

This study has shown a significant increase in sway in anterior-posterior direction in the fatigued state for healthy subjects. This effect can also be observed in the first half of the 5 second interval, but vanishes after the 2,5 second mark. This is an effect of neuromuscular changes induced by fatigue. Following experiments should attempt to achieve higher transferability by choosing more functional measurement approaches. Future research should be performed in order to investigate the exact time after impact, where equilibrium is established.

7. ACKNOWLEDGEMENTS

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APPENDIX 1: LETTER OF INFORMATION

Dear participants,

Thank you for taking part in our study!

We herewith would like to give you some more detailed information about the experiment you are willing to take part in.

The testing will take place at Wednesday 10th of April and Friday 12th of April in the gait lab of the Fontys Paramedische Hogeschool, Ds. Th. Fliednerstraat 2, 5631BN Eindhoven. You will find the information about the precise time we would like you to come at the end of this document. The experiment will take between 30min and 60min of your time.

By making use of two different testing procedures (seated balance task, single leg drop), we will test your core stability. You will be tested in rest, but also after doing some exercise which will fatigue your lower back muscles. Our aim is to find out what effect fatiguing exercises of the lower back do have on the spinal stability.
You will be asked to sign an informed consent and data like your height and weight will be measured. Furthermore some personal information will be gathered before the testing procedure will start. The received information will be kept anonymously.

There are no risks involved with the testing and it will be build up as the following:

1. seated balance test and single leg drop (10 min)
    - seated balance test: you will be asked to sit down on a balance board. By placing your hands in your lap and by only having ground contact with one foot, your are asked to sit up straight and keep your balance for thirty seconds.
    - Single leg drop: you are asked to jump from a platform (25cm height) and land on your dominant leg. The landing position should be hold for ten seconds.
2. fatiguing exercise of the lower back extensor muscles (5 min)
   - you will lay with your stomach on a table. Your pelvis will be fixated on the table with a belt. You will then be asked to raise your upper body, making a lower back extension throughout the full range of motion of the lumbar spine. The task is to do that until you can not perform the movement anymore.
3. seated balance test and single leg drop (10 min)

In between the tasks you will have some rest.

We would appreciate if you could come in sport clothes and you are kindly asked to keep away from physical exercise, sports, the day before and the actual day of the testing.

In case you are not able to come at the time which is planned for you, please let us know!

We are looking forward to seeing you!

Greetings,

Jutta Prünner and Florian Exner, 4th year physiotherapy students

APPENDIX 2: LETTER OF INFORMED CONSENT

Name:

Date:

I hereby declare to have been informed in a clear and comprehensible manner about the nature, method, purpose and the risks and load of this research. I know that research data and results will be disclosed to third parties anonymous and confidential. I am satisfied with the answers to my questions.

I understand that (manipulations of) photo and/or film material that is collected during this study will only be used for analysis and/or scientific presentations.

I agree entirely with voluntary participation in this study. While I reserve the right to end my participation to this study at any time without giving reasons.

Signature:

APPENDIX 3: PROJECT PLAN ASSESSMENT FORM

Name: Florian Exner Student no:

Date: 1-3-2013

Title: fatigue and stability

General	
- The project plan is according to format	yes
- Spelling and language are correct	yes
Problem description and problem definition (introduction)	
- The problem description is sufficiently clearly formulated	yes
- The problem description reflects social and paramedical relevance	yes
- A concrete and relevant research question (or questions) can be formulated based on the problem definition, including possible sub questions	yes
Objective	
The objective is:	
- Sufficiently clearly and concretely formulated	yes
- Relevant for a selected target group within the (paramedical) professional practice	yes
- Practically feasible	yes
- Achievable within the set time	yes
Project product: not relevant	
The project product:	
- Is in line with the problem definition, research question and objective	
- Is usable for the selected target group	
- Is in line with the client's wishes	
- The product requirements are accurately described	
Activities/method	
Sufficient insight is given into the type of activities and types of sources for the performance of the research and the realization of the product	yes
Time schedule	
- The time schedule gives a global phasing and time investment for the project as a whole and for the coming weeks an increasingly detailed schedule	yes
- Important moments are recorded in the table (typographically noticeable) (e.g. contact moments, handing-in moments)	yes
- The time schedule gives a global task division of the planned activities	yes

Estimated costs

Clear insight is given in:

- The costs to be expected concerning money and hours	no
- The division of these costs (project leader, student, programme)	no

Literature

- Used and planned literature is specific and mentioned to a sufficient extent	yes
- Relevant and recent literature is referred to	yes
- Literature references, in the text and in the literature list, are made according to the Writer's Guide (Wouters 2012)	yes

Comments:

Some more details are required Davidson 2004 and 2009 on balance in stance. Functional task properly introduced and related to relevant sports. Good references. Adding "deep" to the research question is probably not realistic...probably all back extensors will be fatigued. Study by Wilson could be explained in a bit more detail. You may want to add more "theory" about the relation between core stability and lower extremity injury risk (articles you refer to were Cholewicki and Zazulak): WHY is there an association? Biomechanical aspects of placement of the center of the trunk should be taken into account.

Methods: CoP is not a fictive point... it is a real point...but I know what you mean. Sway is measured as the Root Mean Square of the CoP signal in both X, Y and vector direction. We will work this out during/ after data collection.

Estimated costs are not presented, but this does not lead to a NO GO assessment.

It appears that some tables are not referred to from the text, and titles and subscripts are lacking.

A picture is referred to as a figure.

Reference list not fully consistent (month).....

In general a properly written project plan. The method section/ procedure gives me sufficient information and confidence that the project can be realised with defined quality standards within the time that is available. A bit more theoretical reasoning in the introduction is wished for.

Good luck!

GENERAL: GO

Name assessor: Jaap Jansen

Date + Signature 16-4-2013

Chris Burtin

16-04-2013

APPENDIX 4: CONVEYANCE OF RIGHTS AGREEMENT

AGREEMENT

Pertaining to the conveyance of rights and the obligation to

convey/return data, software and other means

The undersigned:

1. Mr Florian Nikolas Exner residing at 50321 Brühl, Germany at the Obermühle 5 hereinafter to be called "**Student**"

and

2. Fontys Institute trading under the name Fontys University of Applied Sciences, Rachelsmolen 1, 5612 MA Eindhoven, hereinafter to be called "**Fontys**"

CONSIDERATION

A. Student is studying at the Fontys Paramedic University of Applied Sciences in Eindhoven and is performing or will perform (various) activities as part of his/her studies, whether or not together with third parties and/or commissioned by third parties, as part of research supervised by the lectureship of Fontys Paramedic University of Applied Sciences. The aforesaid activities will hereinafter be called "**Lectureship Study Activities**". At the time of the signing of this Statement, the Lectureship of Fontys Paramedic University of Applied Sciences supervises in any case the studies listed in Appendix 1, but this list is not an exhaustive one and may change in the future.

B. It is of essential importance to Fontys Paramedic University of Applied Sciences that (the results of) the Lectureship Study Activities can be further developed and applied without any restriction by Fontys Paramedic University of Applied Sciences and/or used for the education of other students. Fontys wishes in any event – but not exclusively – (i) to be able to share with and/or convey to third parties (the results of) the Lectureship Study Activities, (ii) to publish these under its own name, where the Student may be named as co-author providing that this is reasonable under the circumstances, (iii) to be able to use these as a basis for new research projects.

C. In case intellectual ownership rights and/or related claims on the part of Student will be/are attached to (the results of) the Lectureship Study Activities, parties wish – taking into account that which was mentioned under (B) – Fontys Paramedic University of Applied Sciences to be the only claimant with regard to said rights and claims. The Student therefore wishes to convey all his/her current and future intellectual property rights as well as related claims concerning (results of) the Lectureship Study Activities to Fontys, subject to conditions to be specified hereafter;

D. Student furthermore wishes to enter into the obligation – again taking into account that which was mentioned under (B) – to convey all data collected by him/her as part of the (results of) the Lectureship Study Activities to Fontys and not to retain any copies thereof, and also to return all data, software and/or other means previously provided by Fontys as part of (the results of) the Lectureship Study Activities, such as measuring and testing equipment, to Fontys without retaining copies thereof, all the above being subject to conditions to be specified hereafter.

AGREE THE FOLLOWING

Conveyance of intellectual property rights

1.1 Student herewith conveys to the Fontys Paramedic University of Applied Sciences all his/her current and future intellectual property rights and related claims concerning (the results of) the Lectureship Study Activities, for the full term of these rights.

1.2 Intellectual property rights and/or related claims are understood to refer to, in any case – but not limited to – copyright, data bank law, patent law, trademark law, trade name law, designs and model rights, plant breeder's rights, the protection of know-how and protection against unfair competition.

1.3 The conveyance described under 1.1 shall be without restriction. As such, the aforesaid conveyance shall include all competences related to the conveyed rights and claims, and said conveyance shall apply to all countries worldwide.

1.4 Insofar as any national law requires any further cooperation on the part of Student for the conveyance mentioned under 1.1, Student will immediately and without reservation lend such cooperation at first request by Fontys Paramedic University of Applied Sciences

1.5 Fontys accepts the conveyance described under 1.1.

Waiver of personal rights

2.1 Insofar as permitted under article 25 'Copyright' and any other national laws that may apply, Student waives his/her personal rights, including – but not limited to – the right to mention Student's name and the right to oppose any changes to (the results of) the Lectureship Study Activities. If and insofar as Student can claim personality rights pursuant to any national laws notwithstanding the above, Student will not appeal to said personality rights on unreasonable grounds.

2.2 In deviation from that which was stipulated under 2.1, the Fontys Paramedic University of Applied Sciences may decide to mention the name of Student if this is reasonable in view of the extent of his/her contribution and activities.

Compensation

Student agrees that he/she will receive no compensation for the conveyance and waiver of rights as described in this Statement.

Guarantee concerning intellectual property rights

Student declares that he/she is entitled to the aforesaid conveyance and waiver, and declares that he/she has not granted or will grant in future, license(s) for the use of (the results of) the Lectureship Study Activities in any way to any third party/parties. Student indemnifies Fontys from any claims by third parties within this context.

Obligation to convey/return data, software and other means

5.1 At such a time as Student is no longer performing any Lectureship Study Activities and/or is no longer a student at Fontys, Student is obliged to convey to Fontys all data, in the widest sense of the word, collected by him/her as part of (results of) the Lectureship Study Activities, including – but not limited to – studies and research results, interim notes, documents, images, drawings, models, prototypes, specifications, production methods, process descriptions and technique descriptions.

5.2 Student guarantees not to have kept any copies in any way or form of the data meant under 5.1.

5.3 Student is obliged to return to Fontys all data, software and other means provided to him/her by Fontys as part of the Lectureship Study Activities, and guarantees not to have kept copies in any way or in any form, of the provided software and/or other means.

5.4 Student agrees that if he acts and/or proves to have acted contrary to the obligations mentioned under 5.1 up to and including 5.3, (a) he/she shall be liable for all and any damages incurred or to be incurred by Fontys, and (b) that this will qualify as fraud and that Fontys can apply the appropriate sanctions hereto. The sanctions to be applied by Fontys may consist of, among other things, the denying of study credits, the temporary exclusion of the Undersigned from participation in examinations, but also the definitive removal of the registration of the Undersigned as a student at Fontys.

Waiver

Student waives the right to terminate this Agreement.

Further stipulations

7.1 Insofar as this Agreement deviates from the Student Statute, this Agreement shall prevail.

7.2 This Agreement is subject to Dutch law. All disputes resulting from this statement will be brought before the competent judge in Amsterdam.

Student:	**Fontys Institute**
	trading under the name Fontys Hogescholen
	Supervisor:
Name: Florian Nikolas Exner	Name: Jaap Jansen
______________________________	______________________________
(signature)	(signature)
Date:30/5/2013	Date:__/__/_____
Place: Eindhoven, The Netherlands	Place: ___________________

APPENDIX 5: CONFIDENTIALITY STATEMENT

Confidentiality statement

Name: Florian Nikolas Exner Student No°: 2147487

Title: The effect of back extensor muscle fatigue on dynamic motor control, after a drop jump

____

Content (description)**:**

Introduction: In recent years some researchers investigated the effect of lumbar muscle fatigue on postural control in quiet standing and sitting. The goal of this study was to transfer the question if changes in postural control are visible after fatigue into a functional, dynamic setting.

Research question: Does muscular exhaustion of the back extensor musculature have an effect on dynamic motor control, after a drop jump?

Method: Twenty young healthy students, ten female and ten male, were asked to perform drop jumps from a 25 cm high platform. Ten jumps were recorded in total, five jumps in fatigued and five in an unfatigued state. The intervention exercise consisted of back extensions on a 45° inclined treatment bench until maximal exhaustion was achieved and aimed for at lumbar back extensor muscle fatigue. Each measurement lasted exactly 5 seconds per drop jump, starting with establishing ground contact. Centre of pressure displacement was recorded using a force plate. This output was processed via space time analyses using Codamotion software.

Results: Significant effect was found in anterior-posterior sway after the fatiguing exercise. No effect in medial-lateral sway was observed. Investigating only the first 2,5 seconds separately gives the same result. No significant results were found in anterior-posterior and medial-lateral direction in the last 2,5 second interval.

Conclusion: The findings of this study show a direct relation between lumbar extensor muscle fatigue and postural control in anterior-posterior direction in a dynamic, functional setting. Neuromuscular changes due to fatigue are likely to be the cause for increased sway. Results appear to cohere with previous research assessing sway in static situations.

Key words: sway, drop jump, fatigue, back extensor muscles, centre of pressure

1. By signing this Statement, the Fontys Paramedic University of Applied Sciences in Eindhoven commits itself to keep any information concerning provided data and results obtained on the basis of research of which is taken cognizance as part of the above practical research project and of which it is known or can be reasonably understood that said information is to be considered secret or confidential, in the strictest confidence.

2. This confidentiality requirement also applies to the employees of the Fontys Paramedic University of Applied Sciences, as well as to others who by virtue of their function have access to or have taken cognizance of the aforesaid information in any way.

3. The above notwithstanding, the student will be able to perform the practical research project in accordance with the statutory rules and regulations.

Student:

Name: Florian Nikolas Exner

____

(signature) Date:__/__/_____

Supervisor:

Name: Jaap Jansen

____

(signature) Date:__/__/_____

Coordinator: for receipt

Name: ___________________________

____

(signature) Date:__/__/_____