Technology in Physical Therapy
Wireless Sensors and the Sensorimotor Training

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Abstract: The usage of evidence based decision making is supported along the different professions in the health care system. State of the art in the physiotherapy, especially in the sensorimotor training is that the therapy planning mainly based on the experiences of the physiotherapist as well as by the information given by the manufacturer and the literature. The aim of this study is to show, that the wireless sensor s are a benefit in planning as well as during the execution of the therapy. Therefore different assumptions were verified. Additionally, a survey about the acceptance and the benefit of the sensors was made. Ten test persons performed a laterality test and the sensorimotor training on three different exercisers. During the whole training the muscle activity as well as the motion data was document by the usage of wireless sensors. Immediately after the training, all test persons fulfilled the survey. The study revealed that is important to investigate the training in more detail. Nevertheless, most assumptions are seen as basic principles, they could not be verified. The evaluation of the surveys figured out, that the usage of wireless sensors can be seen as an advantage, but the application has to be optimized.

1 INTRODUCTION

Use of evidence based decision making is promoted across the different professions along the health care system. Based on multiple issues, the use of evidence has become extensively attractive. One of these issues is the documentation of the great diversity of treatment methods in the management of a variety of different conditions. Additionally, the handling of medical errors as well as the identification of trends in technology assessment (Jewell, 2010).

The current status of the therapy planning mainly rests upon theoretical knowledge, observations just like "trial and error". The establishment of a special therapy was supported by the development and dissemination by a respected authority (Mangold, 2012).

One treatment, which is established in the prevention, the therapy, the rehabilitation as well as in the improvement of the athletic performance is the sensorimotor training (Häfelinger and Schuba, 2010). Induced by the variety of application fields the training itself is going to become more and more attractive. Consequently, the availability of, particularly, specialized equipment is steadily increasing. In contrast, the impact of the training on the body is not yet fully investigated (Rühl and Laubach, 2012).

The positive benefit of the training depends on the correct application of the equipment. Due to the different materials, functions and characteristics of the exercisers the correct usage might be challenging. In particular, the therapy planning is still quite incompletely investigated. Hence, the training is based on the experiences of the individual physiotherapist and additionally by the given background information of the literature as well on the manufacturer's data regarding the exercisers characteristics (Rühl and Laubach, 2012).

The myofascial chains is one method of treatment which is often mentioned in the literature. Kabat has developed a method to integrate weakened muscles in a special muscle chain to optimize their behavior during the execution of certain motion patterns. However, this chains cause the activation of the proprioceptive capabilities of the musculoskeletal system and leads to the strengthening of the weakened muscles. Several different methods derive from the myofascial chains from Kabat. For instance the holistic model of all muscles chains by Struyff-Denys. The

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aim of the application of the principle of the myofascial/ muscles chains is to adopt the behavior of motion from everyday life as well as from sports into the therapy process. Consequently, up to date the principle of the myofascial/ muscle chains is still integrated in the physiotherapists working process (Richter and Hebgen, 2007; Tittel, 2012).

Next to the literature of basic principles of the therapy, a highly important role in the planning of the treatment is played by the manufacturer's information about the exercisers. One popular exerciser is the "Balance Board". It's responsibilities include the strengthen of the musculature of the buttocks, the legs, the back and the abdomen (Sport-Thieme, 2012). Consequently, the following effects were attributed to the training on the Balance Board. Firstly, the improvement of the inter- and intramuscular coordination of the muscles of the feet, the legs, the lumbar spine, the thoracic spine and the cervical spine. Secondly, staying with both feed on the Balance Board, should cause the enhancement of the stabilization in the region of the lumbar spine, the pelvis and the hip (Bertram and Laube, 2008).

The aim of the current study was to show that there is a positive benefit when wireless sensors were used in the sensorimotor training. The usage will lead to an evidence based therapy planing. Furthermore, the effects of the training on the body were investigated in more detail. The research documented the training of ten subjects of three different exercisers. Additionally, test regarding the laterality were made was well as inquiries concerning the acceptance of the measurements.

2 MATERIAL & METHODS

2.1 Measurements

The Shimmer^{TM} measurements are small and wireless sensors. The usage of the Bluetooth technology allows for online data streaming in real-time (Shimmer Research, 2011).

The EMG (Electromyography) daughterboard provides pre-amplification of the EMG-Signal. The non-invasive method represents the whole activity of a muscle using either two or three channel data acquisition (Shimmer Research Support, 2012).

The gyroscope module records the angular velocity of three axis. It consists of a single as well as of a dual axis angular rate gyroscope (Kuris, 2010).

2.2 Exercisers

For the evaluation of the sensorimotor training the behavior of the subjects were documented on three different exercisers.

2.2.1 Balance Board

The Balance Board is an exerciser with a multidimensional instability, figure 1. Its top is made of stable and reinforced plastic with a diameter of 40 *cm*. The height of the board is 9 *cm*. The aim of the training on the Balance Board is in general to strengthen the musculature of buttocks, legs, back and abdomen (Sport-Thieme, 2012).

Figure 1: Balance Board.

2.2.2 Rocker Board

One characteristic of the Rocker Board is its one-dimensional instability, figure 2. Again, there is a diameter of 40 *cm*, but in this case a height of 7.5 *cm*. The aim of the Rocker Board is to train the coordination, the stamina, the strength as well as the motor skills. The Board is either used with a forward-backward or a left-right deflection (Bad-Company, 2013).

Figure 2: Rocker Board.

2.3 Experimental Setup

Supporting the objectives to develop a useroriented experimental setup and to generate a test procedure, which can also be executed in patients therapy, the design of the study was made in cooperation with experienced physiotherapists of a medical school.

The aim of the study is on the one hand to investigate the sensorimotor training and on the other hand to show the benefit of the usage of wireless sensors in the physiotherapy, especially in the sensorimotor training. To have a more detailed look at the sensorimotor training different questions were analyzed:

- Verification of the principle of the myofascial/ muscle chains
- Verification of the manufacturer's data
- Verification of the the given information by the literature, for example exercisers with one-dimensional instability are easier to handle than exercisers with multidimensional instability (Grifka and Dullien, 2008)
- Verification of the correlation of laterality and behavior on the exercisers
- Acceptance of the measurement units

The study involved ten young and healthy subjects (seven male and three female). They gave their written consent to participate after being informed about the test procedure. They perform a special test procedure on each of the three exercisers. Furthermore, a test for the laterality of the hands as well as of the feet were made. Additionally, a questionnaire about the acceptance of the wireless sensors had to be fulfilled by the subjects.

2.3.1 Exerciser-tests

The development of the tests sequences on the exerciser derived from a previous study (Thiers et al., 2013b; Thiers et al., 2013a).

The measurements on the exercisers requires the use of two different types of Shimmer™ sensors. The two gyroscope sensors were places centrally on each exerciser. To verify the different assumption of the manufacturers and the literature the EMG sensors were placed down the legs. In detail: M. biceps femoris, M. vastus lateralis, M. tibialis anterior and M. soleus. Both, the skin preparation as well as the placement of the Ag/AgCl electrodes follows the recommendations of the SENIAM Project (SENIAM project, 2012).

One test sequence comprised of a reference measurement in front of the equipment and the recording on the exerciser. The test sequence had to be performed for each of the three exercisers and the order of the training equipment was randomized for each test person. The measurement on the exerciser was divided into four consecutive phases of changing difficulty and duration, table 1. Another characteristic of the test procedure was the symmetrical requirement to both body sides. All recordings have been done without shoes and were supervised by an experienced physiotherapist.

Table 1: Test procedure.

Phase	Task	Duration
1	Eyes open	30 s
2	Eyes closed	30 s
3	Throwing a medicine ball	60 s
4	Eyes open	30 s

2.3.2 Laterality-test

The outcome of previous studies had shown that there is a dominance body side (Thiers et al., 2013b; Thiers et al., 2013a). Next to the handedness the phenomena of the laterality is also relevant for other paired parts of the body (Weineck, 2004). To establish a link between the laterality and the measured values different test were made. On the one hand the handedness was tested. Additionally, the laterality of the feet was checked, too.

On the whole, six tests for the handedness and ten test for the laterality of the feet were made. For a general overview a balance test was made, too. Therefore the subject had to stand on two scales, with each foot on one scale.

2.3.3 Surveys

To determine the acceptance of the measurement units a questionnaire was developed. Concerning the contents of restrictions during the execution of the trials when wearing the sensors, the benefit of the sensors as well as the transferability of the technology into physiotherapists everyday life.

The surveys were fulfilled by prospective physiotherapists and students of medical informatics.

2.4 Data Analyzes

The data analyzes process started with the application of a notch filter. Additionally, a band-pass filter was used (Merletti and Parker, 2004). Afterwards, the normalization of the EMG data took place. Therefore, the average muscular activity, when staying in front of the exerciser, was calculated and used as normalization value. Hence, the absolute values were transformed into relative values by using the data of the reference measurement and were presented percentage values of the stance.

Next to the normalization a full-wave rectification of the EMG data was made (Merletti and Parker, 2004). To evaluate the recordings in the time domain, different statistical values were computed as interim results. Both, the mean as well as the maximum values were computed over a time window of 512 ms for the whole signal (Gu et al., 2010). Subsequently, the course of the maximum values over time was calculated. Furthermore, the mean value of the maximum voltage values for each phase as well as for the complete procedure were computed. In addition to the previous parameters the accumulated EMG activity (iEMG) was evaluated, too. Firstly, the EMG was integrated over time. The next step comprised of the calculation of the area under the EMG for a chosen time period, also known as iEMG (Robertson and Caldwell, 2004; Medved, 2000). This procedure was performed on the one hand for each phase and on the other hand for the complete test procedure. Furthermore, the course of the iEMG was documented for the whole over time by the summation of the iEMG during the execution of the exercises.

As a complementary evaluation to the physiological data, the motion data was also analyzed. The gyroscope data was low-pass filtered and then the direction of motion as well as the current deflection was computed.

3 RESULTS

The illustration 3 provides a brief overview of the complete muscular activity of each muscle on each exerciser for one test person, a left-hander, during two different trials. After the first execution a short feedback was given to the test persons. A few weeks later the test persons have repeated the whole experimental trial.

The muscle with the highest strain during each trial represents the 100 %. The values of the remaining muscles were presented in relation to the 100 %.

The subject achieved the highest values during trial one with the right M. vastus lateralis as well as with the right M. tibialis anterior. The highest overall strain is documented for the forward-backward Rocker Board. In contrast, the training on the Balance Board seems to be the lowest challenge for the subject. Except the Balance Board, the right body side is always providing the highest EMG values. Trial one figures out the following points: the training on the exercisers with the one-dimensional instability required higher EMG activity than the training on the exerciser with the multidimensional instability. Although, the subject is a left-hander and the laterality test of the feet shows that in eight out of ten tests the preferred leg is the left one, mainly the right body side was dominant. The M. biceps femoris achieved comparatively low EMG activity, this reflects a contrast to the assumption of the myofascial/ muscles chains. In detail, the expected muscle behavior following the theory of the chains of the supporting and the free leg was not documented (Tittel, 2012).

After the execution of the first trial the test persons received a feedback to there individual performance on the exercisers. With a delay of a few weeks the experimental setup was repeated. The documented values were illustrated in the lower part of figure 3. The major outcome is the new sorting of the EMG activity values of the single muscles, which also leads to different levels of difficulty of the exercisers in comparison to the first trail. In this case, the highest muscle strain is achieved by the right M. tibialis anterior on the left-right Rocker Board. Furthermore, the EMG values document, that the forward-backward Rocker Board represents the smallest challenge. Another change is shown in the dominance of the right body side. The second trial documents an increased occurrence of higher voltage values of the left body side.

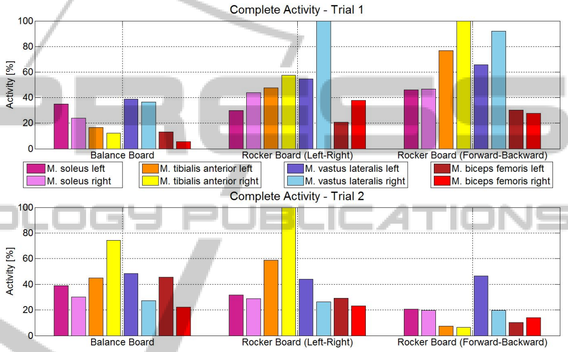

Figure 3: Comparison of two trials of one subject.

The current figure 4 visualizes the average maximum voltage values for each muscle when the subject used the Balance Board.

One finding of the figure is, that for all muscles the lowest values were achieved during the initial phase. Consequently, this indicates that a slow relaxation took place because the first and final phase require an identical task.

A second finding is that the highest values were always achieved by the M. tibialis anterior. Partially the remaining muscles only had produced voltage values, which are similar to that during the reference measurement in front of the Balance Board. This observation speaks against the principle of the myofascial/ muscle chains, again. Additionally, the documented values do not support the manufacturers information. The main part for the maintenance of the equilibrium on the Balance Board is done by the M. tibialis anterior. Already the musculature of the thigh is only slightly involved.

Another outcome of figure 4 is that in most cases the higher voltage values were achieved by the musculature of the right body side. Both, the test of the laterality of the handy as well as the test of the feet result in the dominance of the right side (hand-six out of six right dominance, feet- eight out of ten right dominance). Whereas the balance test on the scales documented a state of equilibrium (29 kg - 30 kg).

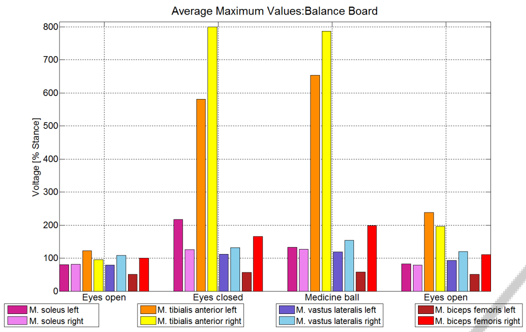

Figure 4: Average maximum values: Balance Board.

Figure 5 documents the results of a set of questions from the survey. Immediately after the execution of the experimental setup the questionnaires were fulfilled.

The first question was about the restrictions during the training when wearing the sensors. No one of the ten test persons had documented to feel any restriction. Next to the small form factor of the sensors the material for the fixation of the measurements is very important for freedom of movement.

The next question addressed the problem of the personal feeling when wearing the sensors. The subjects had to decide whether they feel unpleasant or not. Only one person had reported to feel uncomfortable. This was justified in the temporarily strong fixation of the sensors, which was afterwards optimized.

The third question handled the benefit of the sensors. All test persons have reported to see a benefit of the usage of the sensors. On the one hand the subjects documented that one benefit is to see the muscular activity and to get a feedback. On the other hand the subjects see the opportunity to get objective results about the current state of the therapy.

The last discussion point was the transferability of the sensors into the physiotherapists everyday life. Nine out of ten test persons thought, that it is possible to use the wireless sensors in the practice. Nevertheless, often one point of criticism was mentioned. The application of the electrodes had needed a high demand on time. For an effective usage this application has to be optimized.

4 DISCUSSION

The main finding in this experimental study is that wireless sensors can support the sensorimotor training. On of the most common principles among physiotherapists experts is the method of the myofascial/

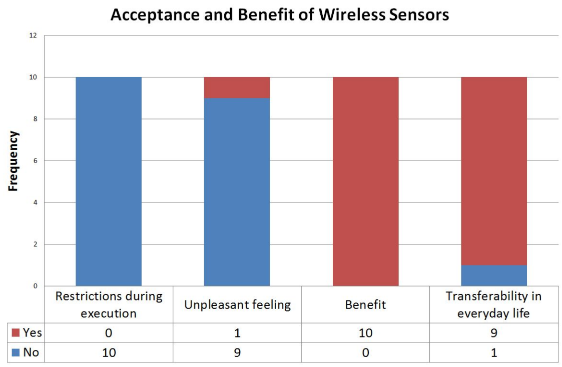

Figure 5: Acceptance and benefit of wireless sensors.

muscles chains. Often the therapy planing is based on this knowledge. However, the EMG patterns of the two subjects have shown that against the expectations, already the ischiocrural musculature only has a limited participation in the sensorimotor training. This observation was confirmed by the EMG values of the remaining test persons, too.

Additionally, the statements of the manufacturer's about their products were validated. Again, this assumption could not be verified. For the characterization of an exerciser more detailed information is needed, for example about its consistency as well as of its inertia.

One assumption about the therapy planning is, that the training on an exerciser like the Rocker Board, which has a one-dimensional instability is easier than on an exerciser with a multidimensional instability. The principle behind: the higher the instability the more the musculature has to stabilize (Grifka and Dullien, 2008). The comparison of the needed EMG activity on the individual exercisers has shown, that the Rocker Board is always requiring the higher participation of the muscles. This observation was made for all of the ten test persons.

Previous studies (Thiers et al., 2013b; Thiers et al., 2013a) have shown, that there is frequently a dominance of one body side regarding the produced voltage values. The analyzes of the motion data has shown, that there is no correlation to the duration of the deflection to one side. Mostly the deflection values have shown that there is a uniform distribution regarding the duration of the individual directions. Hence, there is the assumption, that there is a correlation to the laterality of the subject. Often after the laterality-test there was the recognition that no clear assumption concerning the dominance of the legs could be taken. Nevertheless, the test persons mostly have shown a preferred side. This was also reflected by the EMG values. The ambiguity could maybe caused by the specialization of the test persons in different sports.

The survey figured out, that the subjects have seen a benefit in the usage of wireless sensors in the sensorimotor training. Although, they have critical look at the transferability into everyday life. Therefore, it is needed to perform different improvements to optimize the time exposure.

5 CONCLUSIONS

The investigation of the sensorimotor training reveals that a more detailed look at the therapy planning is needed. In the current study each test person has shown different EMG patterns. Consequently, it is not possible to make general assumptions about the effects of the exercisers. For an effective usage of the equipment a personal analyze of the behavior of the muscles is needed. Therefore the usage of wireless sensors is a benefit.

Furthermore, the correct application of the equipment would be supported, if the manufactures publish more information about their exercisers. Data like the diameter or the height of an exerciser are too general to draw reliable conclusions about the effects the equipment would cause in the training.

All test persons have shown a dominance of one body side. This observation was invisible to the naked eye. Using EMG sensors enables physiotherapist to an objective assessment of the muscle behavior and to adapt the training to the individual performance of the patient.

The great diversity of the voltage values of the muscles of one test person within two trials makes clear that the behavior of the subject is mainly based on its individual form of the day. To handle this challenge the usage of wireless sensor as a real time feedback would be possible.

The variety of different EMG patterns of the individual subjects as well as the differences in the behavior of one test person within two trials shows the necessity of an evidence based treatment in the therapy. This evidence based approach could be realized by the usage of wireless sensors.

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