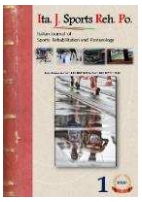

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The beginning of 'striker foot'(Pes equinus varus) with severe stroke patients

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Abstract.

An exploratory investigation into identifying the answers to two specific questions related to this condition.

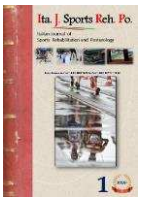
1. *Why do many individuals develop 'striker foot' following severe stroke?*

2. *What is the best intervention to help control its development?*

The answer to the first question lies within the lack of stability in the paretic leg when the patient attempts to move in bed using the other leg.

With the second question the answer is less obvious,although there are indications that greater stability helps to maintain the muscular tone of the calf leading to better overall control.

Throughout this investigation the only changing factor with stability was the mattresswhich suggested that more would be required to prevent 'striker foot' developing. Therefore further investigations are needed to gain a better understanding and help to reduce the numbers of severe stroke patients who go on to develop this condition.



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Striker Foot (Pes equinus varus) in severe stroke patient.

Introduction

Observing dorsal flexion and eversion in Individuals with neurological conditionsis a clear indicator of declining power and range of movements. With stroke patients this can present in various states of ability from fully ambulant patients to those who are more dependent on wheelchair and patients that remain in bed. In earlier investigations from 2002 until 2005 which took place in a nursing home 'Waelwick' where I was working, all participants in the study displayed this decreased range of movement with the dorsal flexion and the eversion, which was the reason for further exploration into this phenomenon. This initial investigation focused especially on the range of movement and positioning within the hip joint ,pre dominately looking towards the exorotation in the affected hip, to help identify any answers as to why this occurs. The affected hip area is where these extreme changes in the increasing range of movementare most prevalent so it was important to understand why it occurs, and look towards developing interventions which will help to prevent it [(1)].Due to the investigation question being restricted to only looking at the range of movement in the paretic hip, any information relating to the condition 'striker foot' (where the foot is observed in an extension synergy) was not considered within the paper, although there was evidence associated with this condition developing as a consequence.The investigation group included patients who experienced loss of ability for independent movement, which was several months following the initial stroke, which led to difficulties in standing and walking.Each patient was presenting with increased tension in the calf muscle which was fixed which got progressively worse over time. This presentation was observed in several individuals who had experienced a severe stroke. To get a better look atthese phenomena in more detail we commenced further investigations involving a different group of patients and compared the outcomes with the original group from the 2002 to 2005 study. The focus of this second investigation was to develop a more comprehensive overview as to the reasons why patient developed 'striker foot', whilst trying to identify interventions which have an influence on reducing the muscular tone in the paretic calf muscle. The group of patients within the second study as identified had been admitted to the nursing home 'Waelwick' following a severe stroke to receive rehabilitative care.

Literature Search

A review of current literature relating to 'striker foot'in stroke patients was conducted and provided only a small evidence base possibly due to a limited amount of research in this area.The search terms used included, Stroke, Stroke "and"pes equinus, Stroke "and" mobility restraint dorsal flexion foot. A Search of Pubmed produced one article from 2004 [(2)]. Verdie, et al; (2004) identified that following a period of one year after the initial stroke, 86 patient in the study group had signs related to the presence of 'striker foot'.This was the majority of study; although when this was compared with the criteria set by the investigating team related to the presence of 'striker foot' then only 18% of the study group was reported as having this condition. The criterion set by the investigating team was that the patient was unable to perform a positive dorsal flexion when the knee was bent at a 90 degree angle. The patient population in the study found (Verdie, et al; 2004), were different to the study group which was selected at the nursing home 'Waelwick' which makes it difficult to use the outcome of this study as a comparison with the results that we observed. The reason for these differing patient populations was that Verdie, et al (2004), investigated stroke patient who were able to walk, whereas our focus was with a patient group who were either reliant on the use of a wheelchair, or were confined to bed due to their individual physical abilities. With so little scientific research available to us, we were therefore reliant on seeking out the answers to these two questions by exploring the condition with the patient study group who have these decreased physical abilities affecting their ability to walk, incorporating the best practice standards available to us.

Best Practice

The developmental phases of 'striker foot'with severe stroke patient, (who are often located in nursing home), appears to have a very low evidence base within the available literature. What is known from clinical practice is that 'striker foot' is a common condition affecting the position of the foot with many neurological diseases including Stroke, Multiple Sclerosis, Parkinson's Disease, and Dementia, which produces increased problems for the individuals when it develops.' Striker Foot' is where the foot is observed in an extension synergy exhibiting plantair flexion with an inversion position, resulting in limited treatments offering any real benefits, with the exception on occasion of using Botox and tendon elongation. These two therapeutic interventions are part of the overall treatment protocols for two main

rehabilitation centres, and are administered to severe stroke patients to look at increase their individual walking capacity[3].Additional observations with patients who have experienced traumatic brain injuries has identified this same phenomenon occurring with the presence of 'striker foot', with one slight difference where the onset is very rapid, and once present is extremely difficult to promote any recovery.

One of the potential causative factors which has been suggested with respect to the development of 'striker foot' is the amount of pressure exerted from blankets over the patients feet when they are lying in bed although this is still speculation and doubts have been raised frequently over the past 7 decades refuting this suggestion [4]. Within the NDT- world the cause where search in a loss of inhibition of the central nervous system and therefore was it possible that there were static reactions. One such static reaction is the positive support reaction that occurs when pressure is applied to the ball area of the foot.[5&6].Despite using equipment such as a blanket cradle or the intermittent application of using an 'anti-striker foot splint' (also in the form of night splint), the KNGF guidelines for Stroke 2014, identified with prove possibility of level 2, but it is unclear what 'added value' this offers[7]**.** The frequency of occurrence from the initial symptoms of 'striker foot' remains unchanged .As previously mentioned 'Striker foot'is not exclusive with patient following severe stroke, it is often extreme with individuals with dementia, especially towards the late stage of the disease progression, as part of the foetal attitude. The increased tone or'paratonia'[8]**,**can be reduced significantly in patients who are in the foetal attitude by applying pressure to the ball area of the foot using an dynamic orthoses (photograph 1B).This reaction is not directly related to thereduced tone, it is possibly due to the "pushing movement"of the leg in a'pushing away orthoses' influencing changes across the whole body, especially in the head and shoulders with the overall tone reducing, resulting in the 'striker foot' presenting less obvious and less extreme[9&10]**.**As the treatment progresses we see stroke patient who have presented with 'clonus'benefit from its 'positive effects'where increasing pressures applied to the ball area of the foot has results in the 'clonus, movements being eliminated. One possible reason why patients present with 'clonus' movements, could be related to minor perception distortions of the foot positioning within the central brain.Therefore increased pressure applied to the ball area and sole of the foot provides greater stimulation of the nerve pathways, resulting in the central brain increasing its depth of perception leading to the clonus being eliminated.

Photo 1A.
Female patient in a foetal attitude, who exhibits the 'striker foot' condition in both feet. Additionally the tone of the head and the shoulders is increased, (especially on the left hand side).
Her extensive head mass assessment is 4+, because there is total restricted movement.

MAS: see attachment 2.

Photo 1B: A prototype 'pushing away' orthoses.

Possible Cause for the development of the pes equinus varus in severe stroke patient

This is a restriction in the dorsal flexion and eversion within the foot, which presents especially in patient with neurological diseases. The supporting literature suggests that this appears in 18% of patients who have had a stroke but retained the ability to walk [(2)]. Restrictions in the dorsal flexion of the ankle is present in almost every patient who have had a stroke. This observation is also mentioned in the article by Sinkjear, et al; (1994) [(12)]. Sinkjear suggests one reason for this restriction is related to the loss of elasticity in the non-contractile structures of the muscle. Goldspring et al, (1974) came to an different conclusion identifying that following a stroke, the muscle tone is increased after only a short period of time following its occurrence. This helps to explain therefore the success of using therapeutic interventions such as Botox at this stage of the disease progression [(13)]. Changes within the muscle and the non-contractile structures are observed at later period of time following this. John Branten's article from (2000), [(14)]identifies a nuance in which he identifies that both the contractile together with the not-contractile structures have an influence when the restriction begins. This provides

a good basis to suggest that therapeutic interventions such as using Botox for chronic 'striker foot',along with other adjustments, [15]do serve a purpose in decreasing the muscular tone.

Tonus increase in the calf muscle with ambulant patients

Rob de Otter (2005) study [16] considers why the tone of the calf muscle increase in ambulant stroke patients. He was able to show that after a stroke the pattern of excitation in the muscles of the affected leg alters, and then remains constant through the whole period of rehabilitation. The calf muscle itself becomes active earlier than initially thought. Even before the foot touches the ground, as the forefoot moves downwards, the tone of the calf muscle increases. What we observe is the affected leg of stroke patients make contact with the ground much quicker, because during the movement they try to perform an extension movement (extension synergy) therefore increasing stability within this leg.

Hypothesis on the origins of developing 'striker foot'with stroke patientswho are confined to bed.

Patients with dementia who adopt a foetal attitude when lying down use this high tone to help build up their stability whilst in this position. This suggested hypothesis 'creation of stability'provided the basis for providing an intervention which helps to promote the use and understanding of the extreme tone(9).In photograph 1, you get the impression that thisindividual in each other creeps. Although further examination of the tone has shown that there is extension tone in the neckwhilst there is a lesser tone in the trunk. This combined with the tension in the flexion pattern of the arms and the adduction/endorotation of the legs are also extreme high whilst the tone of stomach is low. Interventions were designed to develop an increased stability by using a firm support base complete with an orthese (see photo 1B) that helps to increase the flexion of the legs. In this way pressures on the feet weregreater resulting in a "pushing away"movement type reaction (extension, exorotation and abduction). There was also decreased tone in the whole body especially within the neck and arms.

Photo 2.
Paretic leg (right).
In a resting position the extreme exorotation in the leg especially the hip joint and the striker foot.

The stability of this posture must come out the unaffected leg, which is noticeable by the "push" movement of the heel into the matrass.

Stability within an individual following severe stroke.

With individuals who have had a stroke we can see a paralysis of one side of the body resulting in the trunk, which is the basis for movement of the legs, arms and head,cannot provide optimal function and support to provide good stability.(6,7,18) Klein –Vogelbach (1986), is one of the first people, to focus attention on the existence of the trunk diagonals. Two ventral diagonals traversing from the shoulder through the m.seratus anterior and the stomach muscles to the opposite hip. In addition there also exists two dorsal diagonals, that start in the shoulder and goes fromthe m.latissimus dorsi through the fascia thoracolumbalis to the gluteal muscle on the opposite side.

The diagonals themselves are muscular chains which provide support for any opposite movements that we so clearly see when walking. The dorsal diagonals are especially active in the stand-phase and the ventral diagonals in the swing-phase of the walking pattern.

Nasher (1986) demonstrated in his experiments this diagonal system through an EMG-investigation. When an individual was asked to lift their right arm, the first activity to enable them to do this was observed on the opposite side of the body in the muscles of the spine down toand including the calf muscle. This demonstrated the need for stability to build up first before the arm can be lifted.

Stability within the supine position.

Trunk stability is assessed in individuals using a Trunk Control Test (TCT) with a score lower than 48 being the minimal range indicator. The TCT is regarded as a valid test to measure the possibility of an individual's ability to move around in bed(21). A total score is generated using 4 individual elements of examination (1, turningonto the left side, 2, turningonto the right side, 3, moving to a sitting position on the edge of the bed and 4, remaining sit for minimal 30 sec).All four elements combined provides a maximum score of 100 points with each individual element having a maximum of 25 points.When the individual can do this without assistance. When the patient need assistance then only a maximum of 12 points is given and 0 when total assistance is needed. Any score lower than 48 points provides us with an outcome that indicates the individual requires assistance within all four elements.

This group of individuals typically have difficulty lifting the unaffected leg off the bed.The ability to lift the unaffected leg requires the use of the ventral diagonal which runs from the unaffected leg over to the affected shoulder. Stability in this position is managed by the dorsal diagonal which runs from the unaffected shoulder to the affected leg. When the unaffected leg is being raised the position of the umbulus (navel) is changed. The stomach muscles on the unaffected side are required to works harder than the opposite side resulting in the umbulus (navel)repositioning towards the unaffected side. The affected leg, which is part of the dorsal diagonal which traverses over to the unaffected shoulder, is expected to provide the extension and exorotation movement. All of this combines to provide the necessary stability to counterbalance the weight of the lifting leg preventing the body rotating over towards the unaffected side. Despite the individual using the unaffected hand to hold onto the edge of the bed for anchorage, the affected leg will remain incapable of providing adequate stability and will produce an endorotation movement. At this point the individual will lose stability resulting in the need for the unaffected leg to be lowered again, otherwise this would result in an uncontrolled rotation towards the unaffected side. When the leg is extreme hypotonic (Photo 2)stability is completely lost resulting in an inability to lift the unaffected leg. With some tone being present in the affected leg the individual whilst grasping the edge of the bed with the unaffected hand for stability (using the upper part of the dorsal diagonal), you can observe in the affected leg that there is some movement in the hip area with endorotation and adduction

in the knee extension and plantair flexion with inversion in the foot (known as extension synergy). Here the tone/ synergy increasesal though due to having no extension in the hip and inability to complete a full exorotation, the resulting stability attained is very poor resulting in any attempt to lift the unaffected leg results in poor counterbalance and the leg remains heavy resulting in the individual feeling they are rotating to the unaffected side due to a loss of balance.

This group of individuals who have had a severe stroke are thus incapable to lift the unaffected leg up from the bed and will develop an extension synergy by moving the unaffected leg and increasing tone in the calf muscle. This way of thinking has led to the need to develop this hypothesis further to identify solutions in the form of interventions.

Investigation questions.

The primary investigation question for this study is:

"Would instability within the supporting area have influenced the increased tone in the calf muscle with individuals who have had a severe stroke? Due to individuals who have had a severe stroke requiring long periods of time in bed throughout the day.

The secondary investigation question is:

"Would it be possible to create better control in the tone of the calf muscle by developing increased pressures using an anti–pressure area bed?"

Investigation population

The control group included individuals who have had a stroke, who have already participated in an investigation with a course of the extreme exorotation of the hip. Data was collected from 2002 to 2005 (1). The resulting participant individuals equaled 10 in total, with a gender distribution of 60% (6) female to 40% (4) male. In comparison the investigation group in the investigation had a TCT outcome which was 48 or lower (21). The gender distribution for the investigation group was exactly the same as the control group.

This group of patient were in bed for periods of time using anti-pressure area mattresses (the make was Duo care with a permanent pressure change of a fast amount of band). The base installation for the mattress selection is correlated to each individual in the investigation group depending on their recorded bodyweight. The control group was received the same treatment

conditions for parity to be maintained. Therefore this study had a total had of 20 participants within the investigation itself.

Method

The composition of the investigation group is required to be as homogenous as possible to the control group to provide the optimum amount of comparable data for the study findings. Therefore a minimum of three weeks pre study period of observation was undertaken before the individual was admitted to the investigation, which allowed crucial information on their progress of recovery following the stroke to be gathered and compared for similarity.Completing this observation allowed us to identify remove aspects related to spontaneous recovery which could occur over the improvements using the intervention. Consequently subjects were selected based on having the same level of recovery and function as with the control group following the 3 week observations. The inclusion criteria is based on the outcome of the three clinical assessment tools with TCT having a maximum of 48 points, Brunstrom having a score of 2-3 and the Barthel Index(BI) having a maximum of 6 before the individual was invited to participate in the study.

When it was clear that the individuals met the inclusion criteria to be part of the investigation group then a further measurement was required to identify the maximum pressure for the anti-pressure area mattress. Prevention of pressure area development was required using increased observation for red spots developing, once assurances were attained that there were no signs of pressure area development then the first measures were obtained, usually after a short period of 2-3 days.

These measurement were then repeated after a 3 weeks period.

The calf muscle tone was tested using the Modified Ashworth Scale (MAS- scale) (22,23 (attachment 2)). The investigation group were compared with the control group afterthree and six weeks post study commencement, and individuals within the investigation group were also compared with each other's previous measurements as a comparison after three weeks.

Control Group (see table 1) provides information on individuals that had 2 weeks or 1 month following a stroke.

Table 1 Control group characteristics

Male /Female	Age	Time passed following a stroke	left /right paretic side.
1. Female	73	4 month	Left
2. Female	89	3 month	Left
3. Male	76	1 month	Left
4. Male	81	3 weeks	Right
5. Female	72	1 month	Right
6. Male	91	2 weeks	Left
7. Female	88	2 month	Left
8. Female	85	1,5 month	Right
9. Male	79	1 month	Left
10. Female	73	4 weeks	Left

When we consider the klinimetric, we observed a very restricted capacity, with an increase in the tone of the calf muscle following a period of three weeks. Coincidentally over the same period there were no changes in the Brunstrom scale, with this observed increase presenting predominately in the calf muscles.

Table 2 Measurement control group

Primary measurement taken at commencement of the study then repeated after three weeks and six weeks.

Patient	TCT 1+ 2	BI 1+2	6 punt Brunstrom1+ 2	MAS. Calf tone On commencement	MAS. Calf tone after 3 weeks	MAS. Calf tone after 6 weeks
1.	36	3	2-3	3	4	4
2.	48	5	3	4	4	4
3.	36	5	3	3	4	4
4.	48	5	3	2	4	4
5.	36	4	3	3	4	4
6.	36	3	2-3	3	4	4
7.	36	5	3	4	4	4
8.	24	4	2	3	4	4
9.	48	6	3	2	4	4
10.	36	5	2-3	4	4	4

Over this period of time no were observed in the TCT, Brunstrom or BI assessment tools.

Table 3 Investigation group characteristics

Male /Female	Age	Time passed of having an stroke	Left /right
1. Male	70	4 weeks	left
2. Female	89	1 month	left
3. Female	80	1 month	Left
4. Male	88	2 month	Right
5. Female	75	1 month	Right
6. Female	70	4 weeks	left
7. Male	76	4 weeks	Left
8. Male	79	1 month	Right
9. Female	69	3 weeks	Left
10. Female	73	4 weeks	Left

Similarly to the control group timescales the first measurement for the investigation group was taken on commencement. After three weeks the TCT, BI, Brunstrom and the MAS assessments were repeated. If no change were observed in the first 3 weeks, then these individuals were ask if they would like to participate in the investigation The initial interventions were tested whilst the maximum pressure in the anti-pressure area mattresses was attained.

After a period of one to two days calf muscle tone was measured, and then repeated after 3 weeks, (See table 4).

Table 4 Measurement Investigation group.

Patient	TCT	BI	6 point scale Brunstrom	MAS. Calf muscle on Commencement	MAS. Calf muscle after support intervention. **	Measurement after 3 weeks
1.	24	3	2	4	3	2
2.	36	4	3	4	3	3
3.		5	3	3	4	3
4.	36	4	3	4	3	2
5.	36	4	3	3	3	2
6.	48	5	3	4	4	4
7.	48	5	3	3	3	2
8.	48	5	3	2	3	2
9.	24	3	2-3	4	3	3
10.	36	4	2-3	3	3	1+

Realize after 1-2 days.

Over the entire study period no changes were recorded in the TCT, Brunstrom and BI assessment tools.

Result

The results indicate clearly that the MAS score with all individuals in the control group is high and remained unchanged over the study. In comparison the investigation group were noted to have a high MAS at the commencement of the study but following the intervention phase 9 out of 10 of the individuals in this group experienced a decrease in this score.

Over the study three remarkable result were observed:

1. The tone of the calf muscle on the affected side increased whilst the individual was treated on an anti-pressure area mattress which was installed and adjusted to the individuals own weight requirements to a MASof 4(control group).

2. The tone of 9 out of 10 individuals in the intervention group decrease after the intervention, where the mattress support area wasfirm. This change in the muscle tone remained significantly reduced following a three week period of observation.

3.Overall comparisons of the two groups identified clearly that afirm mattress affected the total increase of positive development in the calf muscle tone with the individuals following a severe stroke.

Discussion

Although the reliability and the responsivity of the MAS as an assessment tool in measuring the muscle tone has proved to be weak overall it still has a strong degree of validity when it comes to the overall outcome. The negative influence of the measurement of the tone can be improved by ensuring a systematic approach is used with firm agreement on the threshold scores being assessed (22). The measurement that was agreed as part of the study included the need to ensure that the same attitude was taken, that cough has no influence and that the speed of movement was recorded as a 4 digit number(22).During the investigation for consistency of accuracy it was important that the same persons took the measurements for both the control and investigation group. Any decrease in the MAS score of two point was felt to demonstrate clinic relevancy towards positive change with the individual. The study still has several question to explore further including, how the observed improve stability works? Along with identifying any limitation to the intervention itself. Due to the support area being the only

factor identified for the intervention, the investigators felt that there were possible additional differences in the intervention between the two groups which could have influenced the change observed. For instance following the test being explained to the individuals being observed they were asked to lift their unaffected leg, whilst the investigator held onto the entire affected foot (from forefoot to heel) by placing his under arm against the foot sole and holding the calcaneus in his hand in the best possible dorsal flexion position. What was very evident from this position adopted is the individual now had less difficulty in lifting the unaffected leg, leading to the suggestion that this hand technique may help to provide an additional stabilizing factor? Due to the dorsal diagonal getting extra support.

Another difference observed related to lifting the unaffected leg of the individuals in the control group. An increase in muscle tone with all individuals increased up to the maximum MAS and after this lifting this the tone-increase remaining for at least 5 minutes. In the investigation group the movement of the unaffected leg also presented with an increase to the maximum of 4 on the MAS, but when the unaffected leg was put down, the muscle tone of the calf decrease almost immediately to the initial level before treatment. This led to the need for further understanding as to why this was so different between the two groups?

Further investigation is required to explore these questions looking to develop towards a more perfect support system.

Clinic Relevancy

The value of having reduced muscle tone in the calf is the increased potential for the individual to assist by the transfer in and out of the bed. A calf tension of MAS 2 provides adequate control and has no negative influence when carrying out the transfer whilst weight bearing.

A tone of MAS 3-4 produces additional inhibition of movements to the affected leg when transferring with optimal weight making the transfer extremely difficult or even impossible. Consequently the transfer will need to be made by increasing the support offered by the unaffected leg.

Previous investigation as far as far as we know have not been undertaken to identify this aspect, especially with individuals who have had a stroke. In the nursing home 'Waelwick' the physical therapist provides exercise and training to individuals on the ward, on a daily basis (this offers better context training) aimed to improve the transfers in and out bed. Although

the primary goal was to maintain the individuals rest capacity, the subsequent phases looking at taking measurement of the investigation primarily indicated no immediate changes, although a number of individuals did show some improvement in function over an extended period of several years. Five out of ten individuals improved to the point of being able to come to a standing position with assistance whilst placing weight on their affected leg. They also managed to walk with a walking aid and supervision. In comparison the control group also showed improvements,but the presence of'striker foot' condition resulted in a significant barrier and slowed down the person's recovery time to reach a point of being able to stand and walk.

Conclusion

A correlation between the development of 'striker foot' with individuals who have experienced a severe stroke and the ability to lift the unaffected leg does appear to exist. The increase in the calf muscle tone seems to be higher on a soft unstable surface compared with a hard bed.

An alternative viewpoint is to consider whether movement itself is essential to stimulate the recovery. Movement of the unaffected side works by stimulating the affected side. The affected lower side needs tone which is sufficient to bear the opposite upper sides body weight. Therefore lying on a hard and stable bed seems to have a positive effect on the ability to control and develop the tone evolution of the calf muscle.

Attachment 1.

6 Motor stages of Brunstrom:

1. Flaccid paralysis.

2. Increased muscle tone without active movement.

3.Increased muscle tone with active movement mainly in rigid extension synergy.

4. Increase muscle tone with alternating gross movement in extension and flexion synergies.

5. Muscle tone normalization with some degree of selective muscle control (i.e., combined active knee extension and foot dorsal flexion against some resistance).

6. Normal muscle tone and control.

Attachment 2

MAS Investigation of the tone by passive movement. The speed is defined.

0= normal

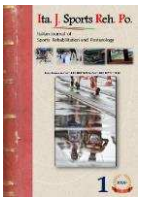
1 =light resistance at the beginning and the end of the joint movement (cut feeling)

1+ = light resistance over more than 50% of the joint movement. ROM = range of motion.

2 = obvious resistance over less than 50% of the ROM, but the range of motion is still total possible)

3 = Strong resistance and the passive ROM is difficult.

4 = ROM only partial possible



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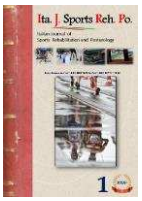

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