Names – Leanne Cascone B. Sc – Clinical Sciences and Patrick McLaughlin B. App Sc (Phys Ed) M. App Sci (Human Movement)

Student No - 3508220

Department – Osteopathic Medicine

Faculty - School of Health Sciences – Victoria University – Flinders Lane Campus

Degree – Master of Health Science (Osteopathy)

Title – The effect of injury on ankle range of motion and proprioception

ABSTRACT

Objective - To assess the effect of injury to the ankle on postural sway in participants with a history of no injuries, one injury and two or more injuries. To compare the changes in passive range of motion of the ankle in participants with no injuries, one injury and two or more injuries.

Background – There is substantial evidence of deficits in ankle range of motion and proprioception in people with recurrent ankle sprains. However, there is only limited information on exactly how much range of motion and proprioception is lost, when the ankle is sprained

Methods – Forty-five participants aged between 18 and 40 (mean 22.3, ± 9.37) were recruited and divided into three groups. The first group had not sustained ankle sprains. The second had sustained one injury to one ankle and the third had sustained two or more injuries to one ankle. Ankles were tested passively in all ranges of motion. Proprioception was then tested using a force platform. Each participant was asked to balance on one leg with their eyes shut for ten seconds. Data from all ranges of motion and proprioception were compared between the non-injured ankle to the injured one, and differences between the three groups were compared.

Results – The inversion range of motion was found to increase significantly between the non-injured group and the group which had sustained one injury ($P = 0.013$.) Proprioception movement (Y- range) and length of centre of pressure, were found to increase gradually as the number of injuries increased.

Conclusion - The results suggest that there are some changes in inversion range of motion and some deficits in proprioception once an ankle injury has occurred

Relevance – It is known that once the ankle is injured there are changes in both range of motion and proprioception of the ankle. The testing of participants with different numbers of injuries allow us to determine just how much motion and proprioception is lost with each injury.

Key Words - Proprioception, range of motion, ankle injuries, ankle

INTRODUCTION

Ankle sprains comprise up to 10% of all sports related injuries. Therefore, the ankle sprain is the single most common injury in sport (Pellow and Brantingham, 2001). Approximately 47% of all ankle sprains that occur have previously been sprained (Wright et al., 2000). Among athletes, it has been reported that the re-occurrence of ankle injuries is as high as 80% (Denegar et al, 2002). The most commonly injured ligaments are the lateral ligaments, which comprise of the anterior talofibular, posterior talofibular and the calcaneofibular ligaments.

After injury, even once recovery and rehabilitation has finished, there are still deficits that remain as a result of the injury and the scar tissue that forms. Denegar et al. (2002) reported that during clinical examination of the ankle, there was a decrease in proprioception, neuromuscular control, range of motion and an increase in ligamentous laxity. The author proposed that it is these deficits that contribute to the recurrence of ankle injuries. Studies into the effect that injury has on proprioception and range of motion has been performed, but only in certain athletic populations such as basketball (Payne et al., 1997) and dance (Leanderson et al, 1996 and Wiesler et al, 1996).

Proprioception is defined as "sensory nerve terminals, found in muscles, tendons and joint capsules, which give information concerning movements and position of the body" (Dorlands, 1994, pp. 1364). Proprioception deficits have been recorded using various machinery, one of which is a Biodex stability system machine. This equipment was used in a study conducted by Rozzi et al. (1999) who determined that biodex machine was reliable instrument to test for prorioception (intra- class correlation between 0.6-0.95). A study by Payne (1997) also used a Biodex machine to test proprioception. Payne et al. (1997) used forty-two subjects (31 women and 11 men) and reported that there were proprioceptive deficits in basketballers with previous ankle injuries.

A pedal goniometer has been used to assess position sense or proprioception in the ankle joint. In a study by Boyle and Negus (1998) the goniometer was used to determine position sense of inversion when the ankle was plantarflexed at forty-two degrees. They measured the patients proprioception by placing the participants ankle into an inversion position, then taking it back to neutral and allowing the participant to place their own foot into the same inversion position. This process allowed the measurements to be taken in a position that replicated the direction of most ankle sprains. They determined that there was an increase in active inversion range of motion when the ankle is recurrently injured. The study compared uninjured to injured and the injured group had to have had suffered at least two sprains of the ankle. The current study will add an extra group and assess the deficits when only one sprain has taken place to the ankle. Also a comparison will be made between the participants non- injured ankle and their injured ankle.

Leanderson et al. (1996) investigated proprioception in ballet dancers by assessing postural sway or balance on a force platform. It was found that participants with injury to the ankle produced a larger mean sway and a larger sway area compared to the non-injured dancers. Leanderson et al. (1996) also performed this study on basketballers with previous ankle sprains. The authors used the same method and found similar results. The authors concluded that as postural sway was increased on the injured foot, proprioception must be impaired as a result of ankle sprains.

The chosen equipment to test for proprioception, for the current study, is to use the force platform. This was chosen as the studies using the pedal goniometer (Boyle and Negus, 1998) although reliable with an intra-tester reliability at 0.96 and inter-tester reliability at 0.91 (Chan et al. 1990), were used when the participants were lying down, whereas the force platform tests the participants in a standing position while they are weight-bearing. Ankle injuries occur due to the misplacement of the foot in a weight-bearing position. While the goniometer is a reliable form of testing, the fact that ankles are sprained in a weight-bearing position makes force platform testing more appropriate Hence this is the process authors intend to use to test proprioception. The force platform, has been proven to have an inter-rater reliability of $r=0.96$ and a test-retest reliability (ICC) between 0.44 and 0.95 (Emery, 2003) when meaureing ankle prorioception.

There is quite an extensive amount of research published on ankle range of motion. However, most of the focus has been on dorsiflexion and plantarflexion. Denegar et al. (2002) investigated the effect that lateral ankle sprains have on dorsiflexion range of motion, posterior talar glide and joint laxity. The authors found that after injury there is laxity in the subtalar ($P=0.02$) and talocrural joints ($P= 0.04$) and that there was a decrease in dorsiflexion range of motion ($P = 0.02$.) The authors, however, failed to examine plantarflexion flexibility. Dorsiflexion was measured with the leg in four different positions. The authors used a fluid inclinometer as previous literature

(Rome and Cowieson, 1996) found that this was more accurate than a standard goniometer.

Wiesler et al.(1996) examined ankle flexibility and injury patterns in dancers and analysed all ranges of motion in the ankle. The authors tested 148 dance students of two different styles, modern and ballet dancing. The authors found that out of 94 students, 69 ankle injuries were sustained over a one year period. The researchers measured ankle range of motion in inversion, eversion, plantarflexion and dorsiflexion and the measurements were done with a standard goniometer. Hence, the flexibility values found may have been dependent on who was measuring the range of motion, as each examiner would determine the placing of the goniometer. Without marking the position, the goniometer may be placed in a slightly different position each time the ankle is measured.

Moseley et al (2001) have developed the most consistent and valid process of measuring range of motion. The authors use the application of a known torque and the measurement of the joint angle by protractor and photography. On analysis they found that their process had an intraclass correlation coefficient (ICC) of .97 and an inter-rater reliability of 77%. Moseley et al (2001) also found that goniometric measurement of joint angle only had an ICC between 0.5 and 0.73. Hence, the current study will be using the process that Moseley et al (2001) used to measure range of motion.

The aim in the current study is to examine all ranges of motion using the same process as Moseley et al. (2001) and to examine proprioception with the use of the force platform. The authors will compare the differences in ranges of motion and proprioception between uninjured participants, participants with one injury and those with at least two injuries. Also a comparison will be made between the participants non-injured ankle and the injured one. Hence, we may be able to determine how much range of motion and proprioception is lost or gained compared to each participants normal and how much is lost each time the ankle is sprained.

METHODOLOGY

Participants

Forty-five asymptomatic volunteers, aged between 18 and 40, (mean age – 22.3 years, ± 9.37), participated in the research. Volunteers, with and without a history of ankle sprains were recruited via a poster from the Victoria University and all provided informed consent. The study was approved by the Victoria University Human Research Ethics Committee. Participants were excluded if they had sustained an ankle injury in the last two months as their rehabilitation would not have been completed. Participants were also excluded if they had sustained sprains to both ankles, as the research required one ankle to be injury free so that a comparison could be made.

Apparatus

For range of motion testing, a footplate was constructed to secure the subjects foot. The footplate was used to provide a surface for both the tilt sensor and for the dynamometer to be applied. A hand held dynamometer (Nicholas MMT hand-held dynamometer, Lafayette, IN, USA) was used so that 4.4kg of force was applied to the footplate, to produce approximately 12Nm of torque into all movements of the ankle. This is the amount of force that was used by Moseley et al (2001). A wooden plank was placed under the knee so that the knee would not be placed in hyperextension or flexion during the ankle movements. The plank was strapped onto the subject in Figure 1.

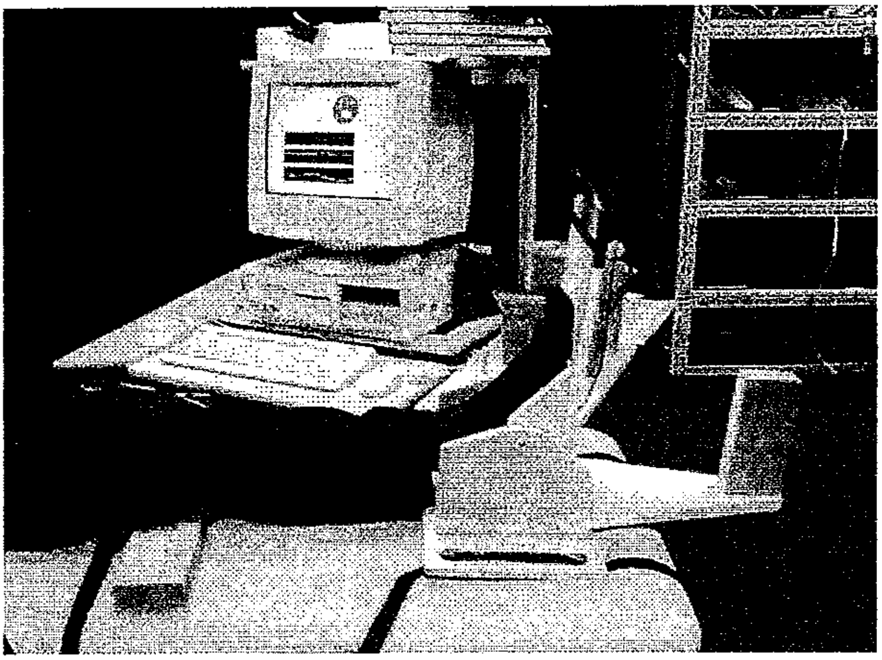

Figure 1 – Set up procedure for range of motion testing

A treatment table was used so that the subjects could lie comfortably. A tilt sensor (3DM electromagnetometer, Microstrain Inc. Williston, VT USA) was attached to the back of the footplate. The tilt sensor measures the angle of inclination of the footplate and would therefore, be able to measure the degree of motion in each range. The tilt sensor was connected into a PC to record the data. The 'Cervical Range of Motion' computer program, produced by 3DM instruments with software designed by Victoria University, recorded all measurements.

For proprioception testing a force platform was used as well as a computer program to assess postural sway while the participant balanced on one foot with their eyes closed for a period of ten seconds

Experimental Procedure

The participants were asked how many times they had sprained their ankle and then were divided into three groups of 15.

Group 1 had not sustained any sprains to either ankle. Group 2 had sustained one sprain to the ankle and group 3 had sustained two or more sprains to the ankle. The participants were asked to lie down on a treatment table in a supine position and their uninjured foot was then strapped into the footplate. The dynamometer was used on the footplate, to place 4.4kg (12Nm) of force into all ranges of motion of the ankle. Flexion was tested first then extension, inversion and eversion Three cycles of testing were performed with the first cycle used to test the participants for any pain or discomfort. If there was no pain, a further two cycles of movement were tested. The computer recorded two cycles. This process was repeated on the injured ankle. For group 1, the dominant foot was confirmed by assessing the participants preferred hopping leg and the dominant ankle was tested first.

To test for proprioception, each participant was asked to stand on the force platform and balance on one leg. The other leg was held at a 90 degree angle so that the shin was parallel to the floor. The participants were then asked to shut their eyes and balance for 10 seconds with their arms by their side. This process was then repeated on the other foot. The force platform bedas software, from Advanced medical technology inc. recorded the amount and direction of movement of the centre of pressure. Measurements, such as the length of centre of pressure (COP) travelled, X-range (the length travelled in a coronal plane) and Y-range (the length travelled in a sagittal plane) were analysed.

Analysis

All ranges of motion and proprioception data was compared between groups using seven separate two-way ANOVAS. This analysis determined if there was any significant difference within groups and between groups for each of the seven parameters by analysing the means and standard deviations. The seven parameters were dorsiflexion, plantarflexion, inversion, eversion, X-range, Y-range and length of centre of pressure. All ranges of motion were measured in degrees while the force platform measured the distance travelled in cm.

Planned Post Hoc analysis was used to determine the location of any differences. An alpha level of 0.05 was assumed with Bonferroni's adjustment at 0.007. All statistics were calculated via the SPSS version 11 computer program.

RESULTS

There were no significant differences found within or between the groups for dorsiflexion, plantarflexion and eversion (Table 1). For inversion range of motion, the results were significant when the non-injured and injured feet were compared ($P = 0.006$ F score- 7.8, Eta^2- 0.085) and when the injury groups were compared ($P = 0.015$.) On Post Hoc analysis the main difference was found to be between groups 1 and 2, between the injury free group and the group with one injury to the ankle where the was a difference of 4.8° in range ($P = 0.013$.)

Postural way in the x-range showed no significant differences within or between the groups (Table 2.) The Y- range group showed some differences in the mean values but not in overall significance ($P = 0.089$.) The means in each non-injured group showed a decrease in sway than the equivalent on the injured foot. In the first group the mean was 7.20° in the non-injured group and 7.45° in the injured. Therefore, the difference between dominant to non-dominant was 0.25°. In the second group the non-injured group had a mean of 6.59° and the injured group had a mean of 7.66°. The difference between the non- injured and injured foot increased to 1.07°. In the third group the mean of the non-injured group was 5.77° and in the injured group it was 8.01°. Therefore, the difference non-injured to injured was at 2.24°. This suggests that there is a small but gradual increase in the Y- range centre of pressure as the amount of ankle injuries increases.

The length of centre of pressure travelled had a significance value of 0.062 suggesting that there were some differences between groups without any injuries compared to those with one and two injuries to the ankle. In the first group there was only a difference of 1cm in the means. In the second and third the difference in the means were up to twenty-two suggesting that once the ankle is injured the length of centre of pressure increases dramatically. The standard deviation of the means increased to 66 and this may be the reason why the results were not significant.

DISCUSSION

The changes that occur in range of motion and prorioception once the ankle is sprained have been widely investigated (Denegar at al. 2002, Lui et al, 2001, Kein-Steiner, et al, 1999, Leanderson et al, 1996). Denegar et al. (2002) found that there was a significantly greater ligament laxity at the talocrural and subtalar joints but was unable to prove that there were any significant differences in dorsiflexion and plantarflexion range of motion when comparing chronically injured ankles to non-injured ankles. When dorsiflexion and plantarflexion were analysed by Weisler et al. (1996), the researchers could not prove that ankle range of motion changed significantly with an increasing amount of injuries and could not confirm that it could be a predictor for future ankle injuries. Both of these studies were performed in an athletic population, whereas the current study was performed on a more sedentary population. Even with this difference in participant group, similar results were still obtained. The results in the current study showed no significant difference for both dorsiflexion and plantarflexion range of motion when comparing the injured foot with the non-injured foot and also when comparing no injuries to one injury and then to two ankle injuries. These findings suggest that overall activity levels may not play a significant role in the changes seen, once an ankle injury has taken place.

Lui et al (2001) investigated passive ankle flexibility in ankles that had previously been sprained. It was found that inversion flexibility of the injured ankle was higher than that of the non-injured contralateral ankle. However, the values were not statistically significant. The injured group had a mean of 10.45° (±- 3.85°) and the non-injured group had a mean of 10.05° (± – 3.84°). Kern – Steiner et al (1999) investigated the effect of unloading techniques for rehabilitation after an inversion ankle sprain. They investigated active range of motion and strength in all ranges of motion, in both the non-injured and injured ankle. They found an overall increase in ROM for both the non-injured and injured ankle. The most significant change came in the inversion and eversion ranges, where the ratios of range of motion increased by 17% or more after the rehabilitation had finished.

The current study found that there was no significant difference for eversion range of motion but there was a significant difference in inversion range of motion, especially between the non- injured group and the group which had only suffered from one ankle sprain where there was a change of 4.8° in range ($P = 0.013$). There was no significant difference, however, between the group with one injury and the group with several injuries. This suggests, that the majority of deficits to range of motion, is experienced after the first injury takes place. The current study and the study by Kern-Steiner et al. (1999) both analysed ranges of motion in a non-loading position and observed similar results whereas the study by Lui et al (2001) analysed inversion and eversion ranges of motion in a loading position. The results for the study by Lui et al, (2001) were not significant while the current study and the study by Kern-Steiner et al (1999) were. This suggests that the positioning of participants may influence range of motion measurements especially in the inversion range of motion.

Therapists now use proprioception to assess functional stability in the ankle after injury. It is also becoming the basis for rehabilitation as therapists are now using proprioceptive exercises to restore stability to the ankle (Boyle and Negus, 1998). A study by Leanderson et al (1996) investigating proprioception in ballet dancers, found that once an ankle injury took place there was an increase in the mean postural sway and an increase in the length of centre of pressure. However, as the ankle injuries recuperated and appropriate rehabilitation had been taken, the length of centre of pressure gradually decrease until no significant difference was found. This suggests that with appropriate rehabilitation proprioception can be regained. Similar results were found in a study by Rozzi et al (1999) who investigated the effects of balance training in a functionally unstable ankle. It found that before balance training there were significant differences between the proprioception in the non-injured compared to injured ankles. Once the training was complete the participants were tested again. The researchers found that there was significant improvement in proprioception for both groups. When the groups were compared to each other there was no significant difference in proprioception between the group with injuries to the group without injuries.

The current study did not find a significant difference in the length of centre of pressure. However there were gradual increases in the means of the length of centre of pressure between the groups, suggesting that there is a gradual increase in the length of centre of pressure with an increase in ankle injuries. The difference between the means of the non-injured group and injured group, increased by up to 22cm. However the group with one injury to one ankle showed a mean length of 91cm but a standard deviation of 66cm. Therefore the intra-group variability was high. Also, the studies by Rozzi et al (1999) and Leanderson et al (1996) were performed in athletes and hence, they had a structured rehabilitation program that they had to follow during the study. The current study, however didn't investigate if the participants had undertaken any kind of rehabilitation program and it did not investigate the exercises undertaken or how long the rehabilitation program ran, if one was undertaken at all. This may account for the differences in the results between the previous studies by Rozzi et al, (1999) and Leanderson et al, (1996) and the current study.

When proprioception was analysed the current study also found that there was a gradual increase in the Y-range distance each time the ankle was sprained, suggesting that the proprioceptive imbalance in the ankle is in an anterior to posterior direction. There was no significant difference found when analysing the X- range data suggesting that deficits don't occur in an inversion to eversion direction. These results, however oppose the range of motion findings where there was a significant difference in the inversion range of motion, suggesting that this was the main deficit. Therefore the findings on the force platform were expected to see a significant difference in the X-range to co-inside with the range of motion results, however, our results did not support this expected change.

The fact that rehabilitation was not investigated in the current study may be one of its major limitations as more detail could have been obtained from the participants concerning their rehabilitation programs. This is one facet that could be improved upon in future research where participants could be observed from the time of their injury to their final recovery. Also the current study did not determine the extent of each participants injury. This could be considered another limitation of the research.

Future research, could investigate changes that occur in different grades of sprains rather than numbers of sprains.

CONCLUSION

This investigation suggests that there are some deficits in inversion range of motion after an ankle injury has occurred, and some gradual decreases in proprioception according to the number of injuries that have been sustained. The findings on proprioception deficits are not conclusive and therefore, further investigation will need to be performed. Therefore the directions of proprioception loss may be determined as the results of the current study differed from what has been found in previous studies.

REFERENCES

W.B. Saunders Company, (1994), "Dorlands illustrated medical dictionary", pp 1364

Boyle, J, Negus, V, (1998), "Joint position sense in the recurrently sprained ankle", Australian Journal of Physiotherapy, Vol 34, No. 3, pg 159-163

Chan, MDY, Chu, MYW, Wong, SCK, (1990), "Reliability of the pedal goniometer for the assessment of ankle inversion in the plantarflexed position", Australian Journal of Physiotherapy, Vol 36, Pg 155-160

Denegar, C, Hertel, J, Fonseca, J, (2002) "The effect of lateral ankle sprain on dorsiflexion Range of motion, Posterior Talar Glide, and Joint Laxity", Journal of Orthopaedic and Sports Physical Therapy, Volume 32 Number 4 pg 10-13

Emery, CA, (2003), "Is there a clinical standing balance measurement appropriate fro use in sports medicine? A review of the literature", Journal of Science and mediciane in Sport 6 (4), pg 492 - 504

Gordon, DS, (1988), "Pedal goniometer to assess ankle proprioception", Archives of Physical and Medical Rehabilitation, Vol 69, pg 461-462

Kern-Steiner, Washecheck, Kelsey, (1999) "Strategy of exercise prescription using an unloading technique for functional rehabilitation of an athlete with an inversion sprain", Journal of Orthopaedic and Sports Physical Therapy, volume 5, pp 282-287.

Leanderson, Johan, Eriksson, Ejnar, (1996), "Proprioception in classical ballet dancers", American journal of Sports Medicine, May-June volume 24

Lui, Siegler, Techner, (2001) "Quantitative measurement of ankle passive flexibility using an arthrometer on sprained ankles", Clinical Biomechanics, Volume 16, pp 237-244

Moseley, Crosbie, Adams, (2001) "Normative data for passive ankle plantarflexion-dorsiflexion flexibility", Clinical Biomechanics, volume 16, pp514-521

Payne, Berg, Latin, (1997), "Ankle injuries and ankle strength, flexibility, and proprioception in college basketball players," Journal of Athletic Training, Jul-Sep volume 32, pp221-225

Pellow, Brantingham, (2001) "The efficacy of adjusting the ankle in the treatment of subacute and chronic Grade I and Grade II ankle inversion sprains", Journal of Manipulative and physiological therapies, Volume 24, pp17-24

Rome K, Cowieson, F, (1996), "A reliability study of the universal goniometer, electrogoniometer for measurement of ankle dorsiflexion", Foot and Ankle, Vol 17 pg 28-32

Rozzi, Lephart, Sterner, Kuligowski, (1999), "Balance training for persons with functionally unstable ankles", Journal of Orthopaedic and Sports Physical Therapy, volume 8, pp478-486.

Wiesler, E, Hunter, D, Martin, D, Curl, W, Hoen, H, (1996)"Ankle flexibility and injury patterns in dancers", American Journal of Sports Medicine, Nov – Dec; 24 (6) pp.754-757.

Wright, Neptune, van den Bogert, Nigg, (2000) "The influence of foot positioning on ankle sprains", Journal of biomechanics, volume 33 pp513-519.

Table 1 - Results for Range of motion

Means					
Foot	**Group**	**Dorsiflexion M(SD)°**	**Plantarflexion M(SD)°**	**Inversion M(SD)°**	**Eversion M(SD)°**
Dominant/non-injured	No injury	31.5 (6.1)	54.2 (8.3)	44.6 (5.1)*	33.3 (4.2)
	1 injury	29.7 (5.9)	48.8 (10)	41.3 (3.4)	29.9 (5.3)
	2 injuries	32.9 (6.1)	49.2 (9.1)	43.0 (4.6)	30.2 (4.7)
Non-dominant/injured	No injury	31.7 (6.7)	50.8 (4.8)	49.5 (6.0)*	29.9 (5.6)
	1 injury	29.2 (5.6)	49.2 (9.1)	43.1 (11.4)	28.4 (4.1)
	2 injuries	31.2 (5.0)	51.2 (9.4)	47.7 (4.4)	30.6 (7.0)

* - Denotes values where significant difference < 0.05 was found

Table 2 - Results for Proprioception

Means				
Foot	**Group**	**X - Range (cm)**	**Y - Range (cm)**	**Length of COP (cm)**
Dominant/ non-injured	No injury	5.3 (2.0)	7.20 (3.62)	83.6 (34.4)
	1 injury	4.5 (0.9)	6.59 (2.45)	70 (9.6)
	2 injuries	4.2 (0.9)	5.77 (1.86)	70.6 (13.8)
Non-dominant/ injured	No injury	5.8 (3.2)	7.45 (3.80)	85.3 (34.9)
	1 injury	5.0 (3.6)	7.66 (3.83)	91.5 (65.5)
	2 injuries	5.1 (1.8)	8.01 (3.55)	92.1 (27.8)