REDUCED VOLUMETRIC BONE MINERAL DENSITY AND GEOMETRIC PROPERTIES OF TIBIA IN HIP FRACTURE PATIENTS

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Työn tarkoitus: Tutkimuksen tarkoituksena oli selvittää luun mineraalitiheyden ja geometristen ominaisuuksien puolieroa tibiassa lonkkamurtumapotilailla ja selvittää mahdolliseen luun puolieroon yhteydessä olevia tekijöitä.

Menetelmät: 31 iältään 60-85-vuotiasta miestä ja naista, jotka olivat saaneet lonkkamurtuman keskimäärin noin kolme vuotta aiemmin, osallistui tähän poikkileikkaustutkimukseen. Perifeerisen tomografian (pQCT) avulla määritettiin luun mineraalitiheys ja luun geometrisia ominaisuuksia molempien alaraajojen tibian distaali- ja varsiosasta.. Lisäksi mitattiin fyysistä aktiivisuutta, alaraajojen ojennusvoimaa ja –tehoa, porrasnousuaikaa sekä 10 m kävelyaikaa. Tilastollisina menetelminä käytettiin parittaista t-testiä ja regressioanalyysia.

Tulokset: Murtuneen puolen tibian distaaliosassa luun kokonaistiheys (-5,8%, p<0,001), trabekulaarisen luun tiheys (-4,5%, p=0,001), ja polaarinen hitausmomentti (-6,9%, p<0,001) ja tibian varsiosassa luun kokonaispinta-ala (-3,5%, p=0,004), kortikaalisen luun pinta-ala (-4,2%, p=0,001), ja polaarinen hitausmomentti (-4,7%, p=0,001) olivat merkitsevästi alhaisempia kuin ei-murtuneen puolen. Porrasnousuaika, fyysinen aktiivisuus, puoliero alaraajojen ojennustehossa ja ikä olivat yhteydessä puolieroon tibian varsiosan kokonaispinta-alassa (R^2=0,81). Porrasnousuaika yksin oli yhteydessä puolieroon tibian varsiosan kortikaalisessa pinta-alassa (R^2=0,27).

Johtopäätökset: Lonkkamurtuman jälkeen luun mineraalitiheys ja geometriset ominaisuudet ovat alentuneet murtuneen puolen tibiassa. Poikkipinta-ala on alentunut tibian varressa kun taas tiheys on alentunut tibian distaaliosassa. Fyysinen aktiivisuus ja liikkumiskyky näyttäisivät tärkeiltä tekijöiltä luun hyvän geometrian kannalta.

Luuntiheys, murtumat, tomografia, ikääntyneet

Reduced bone mineral density and geometric properties of tibia in hip fracture patients

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Abstract

Introduction: The purpose of this study was to examine the side-to-side differences in volumetric bone mineral density (vBMD) and geometric properties of tibia in hip fracture patients, and to assess the determinants of the possible side-to-side differences in bone.

Materials and Methods: Thirty-one 60-85- year old men and women with previous hip fracture, an average 34 months earlier, participated in this cross-sectional study. The bone scans were obtained from the distal tibia and tibial shaft of both lower limbs by peripheral tomography to determine vBMD and bone geometry parameters. In addition, physical activity, muscle performance and mobility were measured. Paired t-test and regression analysis were used in statistical analysis.

Results: In distal tibia, total density (-5.8%, p<0.001), trabecular density (-4,5%, p=0.001) and polar moment of inertia (-6.9%, p<0.001) and in the tibial shaft, total area (-3,5%; p=0,004), cortical area (-4,2%; p=0,001), and polar moment of inertia (-4,7%; p=0,001) were significantly lower on the injured side than on the uninjured side. Stair-climbing time, physical activity, side-to-side difference in leg extension power and age were associated with the side-to-side difference in total area of tibial shaft (R^2=0,81) whereas stair-climbing time alone had an association with the side-to-side difference in cortical area of tibial shaft (R^2=0,27).

Conclusions: Hip fracture results in significantly reduced vBMD and deteriorated geometric properties in tibia of the fractured limb. Physical activity and mobility seem to be of great importance for the good quality of bone geometry in hip fracture patients.

Bone density, hip fractures, pQCT, aged

SELVITYS OMAN TYÖN OSUUDESTA

Pro gradu –työni on osa Jyväskylän yliopiston terveystieteiden laitoksen lonkkamurtumapotilaiden terveyttä, toimintakykyä ja kuntoutusta selvittävää tutkimusta. En ole osallistunut tutkimusprojektin suunnitteluun enkä tutkimushenkilöiden rekrytointiin. Aiempiin tutkimuksiin pohjautuvan kirjallisuuskatsauksen olen kirjoittanut itse sekä hakenut siihen tarvittavan kirjallisuuden. Olen suorittanut tutkimuksen luumittaukset perifeerisellä tomografialla ja analysoinut kyseiset luumittaukset Geanie-tietokoneohjelmalla. Taustatietojen ja fyysisen aktiivisuuden selvittämisestä sekä liikkumiskyvyn, alaraajojen voiman ja tehon mittaamisesta ovat huolehtineet projektin muut mittaajat. Olen saanut käyttööni näiden muiden mittausten tulokset SPSS-muodossa. Pro graduni SPSS-analyysit olen tehnyt kokonaisuudessaan itse ja olen itse kirjoittanut tämän artikkelimuotoisen pro graduni.

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Reduced volumetric bone mineral density and geometric properties of tibia in hip fracture patients

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Microabstract

Cross-sectional design was used to examine side-to-side differences in volumetric bone mineral density and bone geometry of tibia in 31 subjects with previous hip fracture. vBMD and geometric properties of bone were lower in the injured than in the uninjured limb.

Abstract

Introduction: The purpose of this study was to examine the side-to-side differences in volumetric bone mineral density (vBMD) and geometric properties of tibia in hip fracture patients, and to assess the determinants of the possible side-to-side differences in bone.

Materials and Methods: Thirty-one 60-85- year old men and women with previous hip fracture, on average 34 months earlier, participated in this cross-sectional study. The bone scans were obtained from the distal tibia and tibial shaft of both lower limbs by pQCT (Stratec XCT 2000) to determine vBMD and bone geometry parameters. In addition, physical activity, leg extension strength and power, stair-climbing time and 10 m walking time were measured. Paired t-test and regression analysis were used in statistical analysis.

Results: Total density (-5,8%, p<0,001), trabecular density (-4,5%, p=0,001) and polar moment of inertia (-6,9%, p<0,001) were significantly lower in the distal tibia of the injured side compared to the uninjured side. In the tibial shaft of the injured side, total area (-3,5%, p=0,004), cortical area (-4,2%, p=0,001), and polar moment of inertia (-4,7%, p=0,001) were significantly lower than on the uninjured side. Time since injury had no association with the side-to-side differences in bone. Stair-climbing time, physical activity, side-to-side difference in leg extension power and age were associated with the side-to-side difference in total area of tibial shaft (R^2=0,81) whereas stair-climbing time alone had an association with the side-to-side difference in cortical area of tibial shaft (R^2=0,27).

Conclusions: Hip fracture results in significantly reduced vBMD in distal tibia and deteriorated geometric properties in tibial shaft of the fractured limb. Physical activity and mobility seem to be of great importance for the good quality of bone geometry in older men and women with hip fracture history.

Key words: Bone density, hip fractures, pQCT, aged

INTRODUCTION

The incidence of hip fractures has been increasing in the recent decades and the increase is predicted to continue [1-5]. The estimated incidence of hip fractures worldwide in 1990 was 1,3 million and the prevalence of hip fractures with disability was 4,5 million [6]. The increasing size of the elderly population is one part of the explanation of the growing figures, but there is still question if the age-adjusted incidence is growing [1, 2, 7, 8]. In Finland, for instance, there were 7122 new hip fractures in people over age of 50 years in 1997 and this figure is predicted to be as high as three-fold in year 2030 if the current trend continues [2].

Hip fracture patients are at higher risk to develop a new fracture than normal population [9-11]. In hip fracture patients the risk of a new fracture in other sites than hip is a 2- or 3-fold compared to healthy population [10, 11] and in certain subgroups this risk may be as high as 8-fold [11]. Especially hip fracture patients with low areal bone mineral density (aBMD) are at high risk for second hip fracture [9].

It has been shown in several studies that an injury of a limb leads to a decline in BMD in the injured extremity resulting in considerable side-to-side differences between the affected and unaffected limb [12-20]. Volumetric bone mineral density (vBMD) has reported to decrease 11% in the distal femur and 19% in the proximal tibia on the injured side during the first six months after hip fracture [21]. According to Zerahn et al. [18] a year after the hip fracture the decrease in aBMD of proximal tibia was 16%. Kannus et al. [13] showed in their study that aBMD is permanently reduced in the injured limb after a femoral shaft fracture. Ten years after the fracture, aBMD was 2-7% lower on the injured side than on the uninjured side distal to the injury site.

Disuse of a limb is considered one of the causes of posttraumatic osteoporosis [22]. Studies on animals and humans have shown that disuse affects not only bone mineral density [23-27] but also geometric and mechanical properties of bone; cross-sectional area [24-26] and mechanical properties of bone [24, 25, 27, 28] have found to decrease following immobilization in animals and spinal cord injury in humans.

However, there are sparse information regarding the relationship between volumetric bone mineral density or geometric properties of bone and injury. Therefore the purpose of this study was to examine the side-to-side differences in volumetric bone mineral density and geometric properties of tibia in hip fracture patients, and to assess the determinants of the possible side-to-side differences in bone.

MATERIALS AND METHODS

Subjects

This study was part of a larger randomized controlled study. Patient records of Jyväskylä Central Hospital were utilized to recruit community-living 60-85-year-old men and women who had sustained a femoral neck or trochanteric fracture within 6 months to 5 years earlier and living in the city of Jyväskylä or neighboring municipalities. An information letter was sent to those patients who had no dementia or malignant condition (n=179). Fifty-five patients responded and they were interviewed over a telephone. Fifteen of the patients did not meet the inclusion criteria (able to move outside without assistance, no amputations in lower limbs and no neurological diseases). In addition to these 40 patients, three patients who contacted the researchers due to a paper advertisement met the inclusion criteria. All together, 43 patients were invited in the laboratory examinations of which eight did not arrive (3 poor condition, 3 forgetfulness, 1chronic inflammation, 1 new hip fracture). In addition subjects with bilateral hip fracture (4) were excluded. Thus, totally 31 subjects participated in this study. In addition, separate analyses were performed for a subsample of 23 subjects who did not have fractures, osteoarthritis or endoprothesis in other joints (than in the fractured hip joint) of lower limbs. The study was approved by Ethical Commitee of the Jyväskylä Central Hospital Board. The subjects signed a written informed consent.

Measurements

Bone density and geometry

The bone measurements were performed with XCT 2000 peripheral quantitative computed tomography (pQCT) scanner (Medicintechnik GmbH, Germany). The quality assurance measurements were performed daily. Distal tibia and tibial shaft of both lower limbs were measured. The measurements of tibia were performed at 5 % (distal tibia) and 55 % (tibial shaft) of the segment length proximal to the distal end plate of the bone. The analysis of the pQCT images of tibia was performed by Geanie 2.1 software (Bonalyse Ltd., Jyväskylä Finland). The density thresholds for bone were set at 169-2500 mg/cm^3 for distal tibia and 280-2500 mg/cm^3 for tibial shaft. In some subjects the lower threshold was too high to include the whole bone area and therefore in these subjects the threshold was set lower but as high as possible. However, the same thresholds were used for both tibias of the same subject. For separating cortical and trabecular bone, S-mode was used for distal tibia (peels 20% from the outer edge of the bone cross-sectional area and this area is considered as cortical bone) and automatic K-mode was used for tibial shaft (separates cortical and trabecular areas automatically using a contour detection algorithm). Total bone mineral density (TotD, mg/cm^3), polar moment of inertia (Ipo, mg cm) (reflects the bone's resistance to bending), trabecular bone mineral density (TrD, mg/cm^3), and cortical cross-sectional area (CoA, cm^2) were determined for distal tibia. In distal tibia, bone marrow was included in the analysis. Total area (TotA, cm^2), polar moment of inertia (Ipo, mg cm), cortical cross-sectional area (CoA, cm^2), cortical bone mineral density (CoD, mg/cm^3), and the ratio of cortical to total area of bone (CoA/ToA, %) were analyzed for the tibial shaft. Bone marrow was not included in the analysis of tibial shaft. The threshold for bone marrow was set at 100 mg/cm^3. The precision of trabecular density, cortical density and cortical area in these tibial sites has reported to vary from 0,7 to 3,8 CV_{rms}% (root mean square coefficient of variation percent) [29]. The side-to-side difference between the lower extremities was defined: 1 - (absolute value of the bone variable in the injured leg/ absolute value of the bone variable in the uninjured leg).

Maximal isometric knee extension strength

Isometric knee extension strength measurements were performed on both sides in a sitting position by using an adjustable dynamometer chair (Good Strength, Metitur, Palokka, Finland). Strength was measured at the knee angle of 60° from full extension with the ankle fastened by a belt to a strain-gauge system. The subjects were allowed to familiarize themselves with the method by doing two to three submaximal trials. Three to five maximal efforts of 2-3 seconds, separated by 30 seconds rest, were conducted. During the measurements, the subjects were verbally encouraged to produce their maximum. For each subject, the best performance with the highest value was accepted as the result. In our laboratory, the coefficient of variation for measurement of isometric knee extension strength is 6,3% [30].

Maximal leg extension power

Extension power of the legs was measured on both sides using the Nottingham leg extensor power rig [31]. The pedal of the rig was adjusted according to each subject's leg length. The subjects were allowed to familiarize with the measurement with two to three practice trials. The subjects were asked to push the pedal as fast and as forcefully as possible. This was repeated for 5 to 10 times until no further improvement occurred. For each subject, the highest value was accepted as the result. The coefficient of variation of leg extension power measurement in our laboratory is 8% [32].

Stair-climbing

In the stair climbing –test the subjects were asked to climb up ten steps (height 16,3-17,2 cm/step) as fast as possible. The starting line was 15 cm from the first step. The subjects were allowed to use a handrail (heights 84cm and 101 cm) on either side for support. The time was measured. In women of similar age as in our study, the reliability of 8-step stair-climbing test measured with ICC is 0,96 [33].

10 m walking speed

In 10 m walking test subjects were asked to walk 10 meters as fast as possible without compromising safety. The subjects were allowed 3 meters for acceleration. Time was measured with photocells. The subjects were allowed to use their assistive device. In our laboratory, CV of walking speed measurement is less than 5% [30].

Physical activity

Each subject was interviewed for Yale Physical Activity Survey [34]. In this study, only part of the survey, summary index of activity dimensions, was used. Each subject was asked how much time the subject spent on each type of activity (vigorous activity, leisurely walking, moving, standing, sitting) during the last month. The score of each activity were multiplied by a weighting factor to get indices for each type of activity. The weights are based on the relative intensity of each activity dimension. The final summary index is the sum of these five individual indices.

Statistical analysis

The data were analyzed with SPSS (11.0) software. The side-to-side comparison of each bone parameter was performed by paired-samples t-test. The associations between side-to-side difference in bone and background or functional characteristics were analyzed for the subgroup of 23 subjects using forward stepping regression analysis. In the regression analysis, the dependent variable was the side-to-side difference in bone variable. Age, time since injury, side-to-side difference in leg extension power, stair climbing time, and physical activity were used as independent variables. Variables with nonsignificant association with side-to-side difference in bone variable were removed from the final regression model. Thus, the final model included only those variables that had a significant association with side-to-side difference in bone variable. The level of statistical significance was set at $p \leq 0,05$. The results are expressed as the mean ± standard deviation and 95% confidence intervals.

RESULTS

The background characteristics of the subjects are shown in Table 1. The subjects were on average 75,2 (SD 7,1) years old and slightly overweighed. They had sustained hip fracture on average three years earlier and majority of the subjects were female.

There were significant differences in properties of bone between the injured and uninjured limb (Table 2). In the distal tibia, total density (-5,8%, p<0,001), polar moment of inertia (-6,9%, p<0,001) and trabecular density (-4,5%, p=0,001) were statistically significantly lower in the injured than in the uninjured limb. There was no significant side-to-side difference in cortical area (0,2%, p=0,749) in distal tibia. In the tibial shaft, total area (-3,5%, p=0,004), polar moment of inertia (-4,7%, p=0,001) and cortical area (-4,2%, p=0,001) were significantly lower in the injured than in the uninjured limb. However, there were no significant side-to-side differences in cortical density (-1,3%, p=0,095) or in ratio of cortical to total area (-1,3%, p=0,280) in tibial shaft.

In the subsample of the 23 subjects that had no fractures, osteoarthritis or endoprothesis in other lower limb joints than in the fractured hip, total density (-5,7%, p<0,001), polar moment of inertia (-7,6%, p=0,001), and trabecular density (-4,0%, p=0,015) were statistically significantly lower in the distal tibia of the injured limb than that of the uninjured limb. There was no significant side-to-side difference in cortical area of distal tibia (0,0%, p=0,970). In the tibial shaft, total area (-3,4%, p=0,010), polar moment of inertia (-6,3% p=0,001) and cortical area (-4,9% p=0,001) were significantly lower in the injured than in the uninjured limb. There were no clear side-to-side differences in cortical density (-1,7%, p=0,073) or in ratio of cortical to total area (-2,2%, p=0,052) in tibial shaft.

The muscle performance characteristics are shown in Table 3. The mean leg extension power and mean isometric knee extension strength were statistically significantly lower on the injured than on the uninjured side. The mean 10 meters maximal walking time was 8,9 (SD 2,7) seconds.

The regression analysis revealed that in the subsample of 23 subjects, stair-climbing time, physical activity, side-to-side difference in leg extension power and age were associated with side-to-side difference in total area of tibial shaft (Table 4). These variables explained 81% of the variability in side-to-side difference in total area of tibial shaft. Stair climbing time was the only predictive variable that explained significantly the variability of cortical area of tibial shaft (R^2=27%).

DISCUSSION

This study showed that in hip fracture patients volumetric bone mineral density is reduced in distal tibia and cross-sectional area is reduced in tibial shaft of the injured limb. Also the estimated bending strength of bone is reduced. Mobility, physical activity, side-to-side difference in leg extension power and age seem to predict the side-to-side difference in cross-sectional area of bone in tibial shaft. A study by Neander et al. [21] using QCT found that volumetric BMD of the distal femur and proximal tibia decreased significantly after a hip fracture. Six months after the injury vBMD had decreased 11% in the distal femur and 19% in the proximal tibia. In our study, vBMD of the distal tibia was 5,8% lower on the injured side than on the uninjured side. However, it must be noticed that our study measured the side-to-side differences whereas the study of Neander et al. was a longitudinal study measuring the actual changes in the injured limb. The measured bone site and the time between the injury and the measurements were also different between these two studies. It is possible that in our subjects the values on the uninjured side are also reduced to some amount lowering the side-to-side differences. Also, in the subjects of our study the side-to-side differences may have been larger earlier and restored to some amount.

Although our study failed to show any association between time since injury and amount of bone lost, it showed that age predicts bone geometry on the injured side. The older the person the larger the cross-sectional area of tibial shaft on the injured side relative to the uninjured side. However, according to a previous study [35], it seems that BMD might be restored after the first year after an injury in elderly persons. Between one and five years after a lower leg fracture aBMD in the injured limb seems to increase but not back to baseline level. Kannus et al. [13] have studied the permanent side-to-side differences after femoral shaft fracture. They found that a decade after the injury side-to-side difference in the proximal tibia aBMD was –4,7% which is of the same magnitude than perceived in distal tibia in this study.

In previous studies the decline in aBMD after a fracture has been larger in trabecular than cortical sites [15, 17, 20, 35, 36]. In a study of Findlay et al. [20] the side-to-side difference in aBMD after a tibial shaft fracture was –19% in the distal region of tibia and fibula, which is mostly trabecular bone, and there was a small, non-significant difference in cortical-rich shaft region. In addition, they reported that in the proximal tibia the side-to-side difference in trabecular volumetric density was 28% and in cortical density 8%. Our results support the previous findings, that lower limb injury causes loss of density more in the trabecular-rich bone epiphysis than in the diaphysis that is mainly cortical bone.

To our knowledge this study was the first to show geometric changes in bone after a lower limb injury. We showed that total and cortical cross-sectional area were reduced in tibial shaft of the injured limb. The results of this study are in line with the study of Eser et al. [25] on spinal cord injury (SCI) patients. Eser et al. showed that SCI patients, who suffer from immobilization, lose bone by reducing vBMD in the bone epiphyses whereas in the shaft bone mass is lost by reducing the cross-sectional area. Since both bone material and geometric properties contribute to bone strength the previous studies measuring only aBMD or vBMD may have underestimated the effect of an injury on bone.

Adequate function of the injured limb appears to be important for good areal bone mineral density. It has been shown that muscle strength or function of the injured extremity is associated with bone loss after an injury [13, 14, 37] In contrast, studies on anterior cruciate ligament injury [19] and leg fracture in children [38] did not find this kind of relationship. It has also been reported that in hip fracture patients improvement in mobilization is positively correlated with changes in aBMD of the proximal tibia of the fractured leg and the non-fractured hip [18]. However, Wehren et al. [39] found no correlation between postoperative care, including physiotherapy, or activity level and aBMD in the uninjured femur after a hip fracture. In our study, side-to-side difference in leg extension power was negatively associated with the side-to-side difference in total area of tibial shaft. However, mobility and physical activity were positively associated with the total area of tibia. The better the mobility (lower stair-climbing time) and higher the physical activity, the larger the cross-sectional area of tibia on the injured side relative to the uninjured side.

The reduced vBMD and geometry after hip fracture can be at least partly explained by changes in patients' loading environment. Daily physical activity has probably decreased after the fracture leading to a decline in bending forces in tibial shaft and compressive forces in distal tibia. Decreased loading has resulted in reduced area in tibial shaft, reduced density in tibial epiphysis and reduced estimated bone strength in both bone sites. However, the more physically active the subject and the better the mobility the less the cross-sectional area of bone was reduced in the injured limb. Therefore, physical activity seems to be important for the good bone geometry in hip fracture patients. It has been also shown that bone loss can be prevented by means of exercise in healthy postmenopausal women. [40]. Thus, the role of loading should be taken into account in rehabilitation of hip fracture patients to maintain the bone health of these patients. However, even high level of physical activity or function after an injury may not totally prevent the bone loss since not only the disuse but also the injury itself and its operative treatment cause inevitably some amount of posttaumatic bone loss [22].

The cross-sectional design of our study does not allow providing information on actual changes taken place after the injury. It could be speculated that the side-to-side difference existed already when the fracture happened or that the side-to-side differences noticed in this study would not be caused by a decline in the injured leg but by an increase in the uninjured leg. There is controversial information on the side-to-side differences in BMD at the time of a hip fracture but despite the possible difference at the time of the fracture, BMD decreases in the injured limb after hip fracture [18, 21]. Also, according to previous findings the BMD in the uninjured leg seems to decrease rather than increase [18, 41-44]. Therefore, it seems likely that the side-to-side differences perceived in this study would be caused by decreases in the injured limb after the hip fracture.

In conclusion, hip fracture results in significantly reduced volumetric bone mineral density and geometric properties at the fractured limb. Deteriorated bone geometry can be seen in the tibial shaft whereas reduced bone mineral density is more prominent in the distal tibia. Physical activity and mobility seem to be of great importance for the good quality of bone geometry in older men and women with hip fracture history. Longitudinal studies are needed to determine the actual changes in bone geometry after a hip fracture.

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Table 1 Characteristics of the subjects (n=31). Mean ± SD (95% confidence interval)

Variable	
Age (years)	75,2 ± 7,1
Weight (kg)	73,1 ± 11,7
Height (cm)	164,3 ± 8,7
Time since fracture (months)	34,4 ± 18,7
Side of fracture	
Right	17
Left	14
Sex	
Female	23
Male	8

Table 2 Properties of bone in the injured and uninjured lower limb and the side-to-side differences between the limbs. Mean ± SD (95% confidence interval), n=31.

	Injured	*Uninjured*	*Difference %*	*p value*
Distal tibia				
TotD (mg/cm^3)	215 ± 51	229 ± 52	-5,8	<0,001
	(197-234)	(210-248)	(-8,1 to -3,5)	
Ipo (mg cm)	5635 ± 1991	6050 ± 2114	-6,9	<0,001
	(4905-6366)	(5274-6825)	(-10,0 to -3,7)	
TrD (mg/cm^3)	186 ± 52	195 ± 50	-4,5	0,001
	(167-205)	(176-213)	(-7,0 to -2,0)	
CoA (cm^2)	236 ± 32	236 ± 30	0,2	0,749
	(225-248)	(225-247)	(-1,3 to 1,8)	
Tibial shaft				
TotA (cm^2)	398 ± 64	412 ± 62	-3,5	0,004
	(374-421)	(389-435)	(-5,8 to -1,2)	
Ipo (mg cm)	3992 ± 1454	4191 ± 1453	-4,7	0,001
	(3459-4525)	(3658-4724)	(-7,4 to -2,1)	
CoA (cm^2)	270 ± 76	282 ± 73	-4,2	0,001
	(242-298)	(255-308)	(-6,4 to -1,9)	
CoD (mg/cm^3)	984 ± 83	997 ± 79	-1,3	0,095
	(953-1014)	(968-1026)	(-2,9 to 0,2)	
CoA/TotA (%)	67 ± 10	68 ± 11	-1,3	0,280
	(63-70)	(64-72)	(-3,8 to 1,1)	

Table 3 Muscle performance in the injured and uninjured lower limb and the side-to-side difference between the limbs. Mean ± SD (95% confidence interval).

	Injured	*Uninjured*	*Difference %*	*p value*
Leg extension power (W), n=25	70 ± 35	89 ± 56	-21,1	0,002
	(55-85)	(66-112)	(-33,9 to –8,3)	
Isometric knee extension strength (N), n=29	223 ± 100	263 ± 126	-15,3	0,005
	(185-261)	(215-311)	(-25,5 to –5,0)	

TABLE 4 REGRESSION MODEL SUMMARIES FOR TOTAL AREA IN TIBIAL SHAFT AND CORTICAL AREA IN TIBIAL SHAFT IN THE SUBGROUP OF 23 SUBJECTS

Variable	*Predictors*	β	*p-value*	R^2 *of the model*
Side-to-side difference in total area of tibial shaft	Stair climbing time	-0,680	<0,001	
	Physical activity score	0,446	0,004	
	Side-to-side difference in leg power	-0,613	0,004	
	Age	0,387	0,045	0,811
Side-to-side difference in cortical area of tibial shaft	Stair climbing time	-0,519	0,033	0,269