STUDIES ON THE FATIGUE-FRACTURE OF FIBULAE OCCURRING UNDER THE SAME CIRCUMSTANCES FROM THE POINT OF VIEW OF PHYSICAL EDUCATION

By

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I INTRODUCTION

In physical training, fatigue is an important affair and yet decrease in the efficiency of operation in exercise does not matter so much. It is most important whether a sport is suitable for elevating physical strength or not. It is good to make efforts to elevate physical strength and to better techniques, operations and sporting records for the purpose of meeting the aim of physical education. However, if one is not given the amount of exercise proper to his physical nature and ability, various kinds of harm may happen to him. What takes part directly in physical exercises is muscles or muscular movements. The physical change taking place with the start of exercises is the atrophy of muscles as the primary fatigue.

According to the author's previous paper "Physical Injuries Caused by the Bodily Exercises" (1956)[1], among 9,225 cases in a year, of physical injuries caused by the exercises, 68 cases are related to fibula fractures, 3% (2 cases) of them belonging to fatigue-fracture. And these 2 cases of fibula fatigue-fracture occurred under the same circumstances, which are rare happenings. Few reports are found on the strength of the bones and the forces acting in running upon the bones. Therefore the author took out these two cases to study and observe them from the point of view of physical training.

II THE METHOD OF STUDY

(1) Cases

The following are two cases which occurred during the boarding together of a baseball team for the winter training.

A ♂ Age: 18

A person had been complaining of a spontaneous ache while running for about a week. The examination by roentgenography proved it to be fracture of a right fibula (Photo. 1).

B ♂ Age: 18

B person had been complaining of a spontaneous ache, under the same circumstances as in A, for two days before being examined. The examination by roentgenography proved it also to be fracture of a right fibula (Photo. 2·3).

The health conditions in the two cases are in the table below.

Sections \ Players	A	B
Stature	162.1 cm	160.3 cm
Weight	55.2 kg	57.3 kg
Round the chest	83.0 cm	82.7 cm
Height above the knee	91.1 cm	88.4 cm
Nourishment	fair	fair
Vertebra	proper	proper
Sight Right	1.5	1.5
Sight Left	1.5	1.5
Colour blindness	weak to crimson green	sound
Tuberculin reaction	17 17	10 10
Reaction judgment	+	+
Pulse	80 times	81 times
Respiation	19 times	18 times
Temperature	36°	36.5°
Lung capacity	3,140 cc	3,640 cc
Strength of the back muscles	145 kg	125 kg
Grip Right	54 kg	39 kg
Grip Left	46 kg	37 kg

(2) **The Constitution of the Ground-soil**

The distance that they ran during their winter training was 20 kilometers to and back. The road was over the second step hills covered with the product—loam—pressed out on the south foot-slope of volcano. The soil of the ground was a pile of volcanic sand and ashes. The upper layer of the accumulation was 5 to 15 meters thick.

(3) **The schedule of the Winter Training**

The aim is to improve physical strength, pliability and agility. As this is a vocational school, the students are liable to lack in bodily pliability. Therefore it requires that they should strengthen their waist and feet, which is essential to playing base-ball. The training schedule for the week is as follows:

Monday

Preliminaries: To take radio exercises in order to make arms, legs and waist pliable.

Main Exercises: Road training for 5 km. To load the waist with sand of about 3 kg. To step up and down about 50 stairs 1000 times at the point of turn. All the members run cheering up one another for about 50 minutes.

Adjustment Exercises: To take the sand off the waist and run round the

Table 1 Table of atmospheric conditions from November 1957 to January 1958

Sections / Months	Number of days in weather					Temperature			Velocity of wind		Amount of rain		Average	Deepest
	fine	cloudy	rainy	stormy	frost	av.	max.	min.	av.	max.	total	max. in a day	humidity	snowfall
November	12	15	5	0	25	7.9	15.0	2.2	1.7	6.7	15.1	7.1	76	
December	14	12	7	1	29	3.3	9.4	−1.9	2.5	10.8	31.5	11.7	75	0.0
January	14	9	4	0	31	−0.2	5.8	−5.8	2.5	8.8	42.2	22.7	71	3.0

Frost First date	Frost Last date	Days of no frost	Snowfall First date	Snowfall Last date	Depth of snowfall (deepest)
11 Oct.	18 May	220	24 Dec.	30 March	15.0

Table 2 Table of atmospheric conditions from November 1956 to January 1957

Sections / Months	Number of days in weather					Temperature			Velocity of wind		Amount of rain		Average	Deepest
	fine	cloudy	rainy	stormy	frost	av.	max.	min.	av.	max.	total	max. in a day	humidity	snowfall
Whole Year of 1956						11.0	16.8	6.1			1003.1	364	78	
November	9	16	8	0	24	6.7	12.7	1.7	1.4	5.7	25.8	7.4	85	1.5
December	11	11	2	0	31	−0.3	5.7	−5.7	1.7	8.3	1.5	1.0	80	2.0
January	16	10	4	1	31	0.1	6.6	−5.7	2.8	9.2	2.5	1.2	70	1.0

Frost First date	Frost Last date	Days of no frost	Snowfall First date	Snowfall Last date	Depth of snowfall (deepest)
21 Oct.	14 May	206	30 Nov.	22 March	11.0

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ground 2 times (one round=200 meters). To take radio exercises.
Tuesday The same as on Monday.
Wednesday
Preliminaries: To take radio exercises.
Main Exercises: To run round the ground 15 times cheering up one another. Mat Work Techniques: To rotate back and forth, to rotate back and forth opening the legs, to rotate sideways, to stand on head, and to exercise on a horizontal bar in order to cultivate agility, pliability and decision.
Adjustment Exercises: To take radio exercises.
Thursday
Preliminaries: To take radio exercises.
Main Exercises: Road training of 5 km with sand. To exercise footwork with a signal of whistles on the ground. To exercise on a horizontal bar more than 5 times.
Adjustment Exercises: To take radio exercises.
Friday: The same as on Monday and Tuesday
Saturday
Preliminaries: To take radio exercises.
Main Exercises: Road training of 5 km with sand. Mat work Techniques: The same as on Wednesday.

On this day—twice a month—all the members as a group run as far as possible, about 20 km.

Remarks: The schedule for the week is repeated during the turaining.

(4) **Atmospheric Conditions**

The following are the tables of atmospheric conditions for the last three periods of winter during which the schedule was carried out.

(5) **The Degree of Fatigue**

Fig. 1 is obtained from comparing the first kind of fatigue caused by a short time of physical exercises with the model figure of the Sasagawa's classification[2]. The training proved physically reasonable as a method of training.

Fig. 2 is a comparison of the degree of fatigue for the amount of exercise for a day. There was almost no difference in the amount of exercise between in the first kind of fatigue and in the second kind of fatigue. But in the second kind there was insufficient sleep and some inharmony in bodily adaptation. It is clearly seen in the curved line at T_3, T_5 and T_6.

The two persons whom the author examined were injured in the occurrence of the third kind of fatigue. Their daily fatigue was too much for their own physical strength and could not be cured by one night sleep, remaining in the following day, until at last the accumulated fatigue caused a fracture five and twelve days—a typical period—after the boarding together was started. Fig. 3 represents this in a simple way.

As to the items of fatigue in the table, an examination was done, by means of the judgment by experience, by asking them and filling up the cards about the following questions.

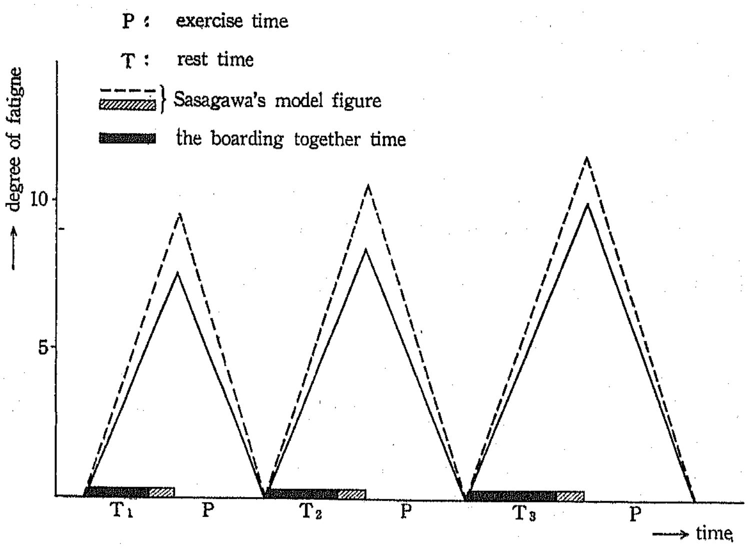

Fig. 1 The first kind of fatigue

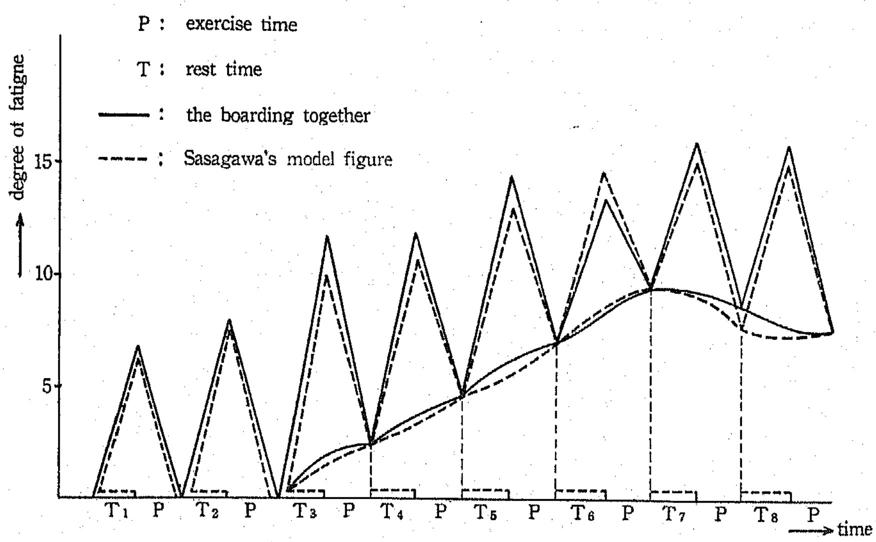

Fig. 2 The second kind of fatigue

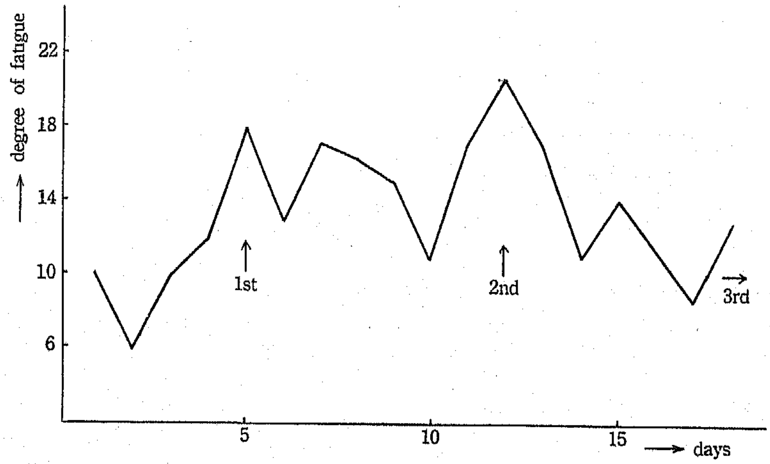

Fig. 3 The third kind of fatigue

1. Are you very tired with a day's exercises ?
2. Are you less spirited than usual ?
3. Do you feel lazy ?
4. How is your bodily condition when you got up in the morning ?
5. How is the luster of your skin ?
6. Do you get out of breath and does your heart thump when you step up and down the stairs ?
7. Are you liable to have loose bowels ?
8. Do you want hard to drink much tea and hot water at meal-time ?
9. Which do you like better, normally boiled rice or rice-gruel ?
10. Do you get irritated ?
11. How many hours a day do you sleep ?
12. Do you sleep sound ?
13. Are you wakeful sometimes ?
14. Are you tired soon of studying your lessons ?
15. Are your fingers and toes benumbed any time ?
16. Do you have abdomen-ache when you pass urine ?
17. Do you have pains in every joint of your body ?
18. State the names of the notable diseases you have suffered from before.

III ON THE SINGLE FRACTURE OF FIBULAE

Statistical studies on bone-fractures have been reported before by many researchers, among them Mr. Tomosuke Maeda[3] reported 2.6 % of the fibula single fracture of all the cases, and Bruns 2.0 %. Mr. Tetsuya Otsuka[4] also has recently reported 392 instances of the lower extremity fracture of all the cases 3076 and 40 (1.3 %) of the fibula single fracture of them. In the previous reports the causes are not described in detail. Mr. Maeda explains simply that the single fracture of fibulae is caused all by the direct force. It is really interesting at any rate that there happened as many as two cases of the fibula single incomplete fracture caused by the indirect force. In Otsuka's report there are 5 cases of the fibula single incomplete fracture, but, to our regret, the causes are not described in it at all.

(1) **The Strength of Fibulae**

Many experiments have been reported on the strength of a bone, and some papers appeared on the studies of dynamical load on it[5]. However, almost all of them are based on statical load on a dead bone, and so this is not enough to assume the cause of fracture.

From the calculation based on Messerer's experiments[6], taking the length of a fibula to be about 35 cm, the values about 60 kg in compressive strength, 500 kg-cm in bending strength, and 100 kg-cm in torsional strength respectively are obtained at the middle of the fibula.

Photo. Fig. 3 shows the cross-sections of the upper middle part of a grown-up man's fibula. The length × width's measured are generally 16 mm × 10 mm to 14 mm × 12 mm. The shape is varied, being nearly in the form of an ellipse of about 8 mm × 4 mm in the hollow part.

The modulus of section at that place about one third above the fibula which was fractured in this case was about 200 mm^3 when the length was the axis, and about 400 mm^3 when the width was the axis. According to Mr. Maeda's study, as the ultimate strength of a dead bone against bending is 24.4 kg/mm^2, the bending strength in this part is about 490 kg-cm, which is very near the estimated value based on Messerer's experiments. It seems that the value calculated above is quite reasonable under the statical load on a dead bone.

As these cases are of imcomplete fracture, the cross-sections at the fractured part are recognizable only in part even in the x-ray photographs Figs. 1 and 2. It is clearly seen that callus is produced there, and since it is said to be produced much on the compressive side; it was presumably bent to the outside. But it is improper to judge so only by such photographs.

(2) **Consideration in Connection with Kinesiological Mechanics**

The energy expended in running is said to be lost a great deal by the friction within the body. And it is difficult to estimate precisely the force of each of the muscles displayed in exercise.

If the time from the foot setting on the ground to its leaving is t_1, the time of the feet floating in the air t_2, the average force of the foot kicking the ground F, the angle of the force with the horizontal direction α, the air resistance D, the weight of a person W, and the running speed constant, then

$$D(t_1+t_2)=Ft_1 \cos\alpha$$

$$W(t_1+t_2)=Ft_1 \sin\alpha.$$

As it is generally said that $D \doteqdot \frac{1}{50}W$ when the speed is medium, ignoring this we obtain $F = \frac{t_1 + t_2}{t_1}W$.

$\frac{t_1 + t_2}{t_1}$ can be clarified precisely by means of the high-speed motion pictures, and, simply speaking, it is the ratio of the distances of the center of gravity moving between the stride and the t_1. If $t_1 = t_2$, then $F = 2W$.

When the ground is kicked with the tiptoe, the maximum value of the force is much greater than the average value F. Considering the balance of the moment around the foot joint, still more force acts upon the Achilles' tendon, varying with the angle of the ankle. But considering that *M. gastrocnemius* has charge of a considerable part of the force, and from the way in which *M. Soleus* attaches itself to the fibula, the bending moment of as many as 500 kg-cm cannot arise about the fractured part. This is the same with the other muscles attaching itself to the fibula such as *M. peronaeus longus.* But the action of *M. biceps femoris* attaching itself to *Capitulum fibulae* is so powerful as to cause the fracture of the fibula sometimes and therefore a considerable amount of moment can arise about *Ligg. capituli fibulae.* At any rate it is believed that, since no fracture can occur under normal conditions, the breakdown has been caused by "fatigue" in the interpretation of strength of materials by the alternate bending moment of *Mm. flexores* group and *Mm. extensores* group and by the repeated compressive load.

Such studies are still rare in number at present and are desirable to be done furthermore[7]. Above all, the most complicated matter in these studies is that there is a ceaseless recovery of fatigue in the living body.

IV CONCLUSION

By this study the author could make sure of the common symptoms among many subjective and objective symptoms in the phenomenon of fatigue. The fracture occurred at the times of the primary and the secondary fatigue, as seen in those cases, although varing according to the degree of work, the season, the constitution and the soil. In other words, special care must be taken of it for five to thirteen days after the boarding together has started, in case the schedule is for three weeks. It is necessary to study the sensation of muscle-movement extensively and to know the great influence of muscle-movement on individuals. Thus to teach excellent techniques and to give self-confidence to them and then to let them avoid injuries should be aimed at. Further concrete notices are as follows:

1. Scientific arrangement of training program and further study of rational arrangement of training days are necessary.

2. Unless good care is taken of the accumulated fatigue, exhaustion by fatigue comes to him at once.

3. It is necessary to know exactly the degree of change in each part of the body when a certain exercise by a certain method has been given to him, and to know the degree of fatigue by estimation.

4. Scientific examination of the soil and the road, and studies on the

hardness, the inclination, the radius of curvature and the distance are necessary before it is carried out.

5. Special attention must be paid to his subjective symptoms.

6. At the time of the secondary fatigue, complete rest must be given to him and his mental conditions stabilized.

This is the study of what took place during the winter-training of the baseball team belonging to a senior high school in which period importance was attached to fundamental techniques, cultivation of physical strength and fostering of cooperative spirit. It was planned scientifically and was performed with great care. But no care was taken of the fatigue caused by the training and its recovery, and so it caused the consequences in question.

The change and sensation, especially muscle-ache, that will appear in the muscles and nerves must be taken care of while in practice. This is caused by the stimulation of the terminal organs of the sensory nerves by metabolic substances produced in the muscles, and by the changes in the physical properties and elasticity of the muscles. Therefore it is important to guide them in the training having these facts in mind.

The reason why the author has titled this report "from the Point of View of Physical Education" is that there exists some scientific relation between medicine and physical education. From this point of view the author observed and studied it fundamentally and synthetically, although there may be much more to be desired in this study.

The phenomenon of fatigue is still unresolved and the method of judgement was in a simple way. However, studies were carried out mechanically this time on the fracture by fatigue, which needs much more study in the future. As further investigations are under way on the fractures in every case, their results will be published on the next occasion.

In conclusion, the author wishes to acknowledge his indebtedness to Assistant Professor Uchida of this faculty for the knowledge of mathematical calculation and kinesiological mechanics; to Dr. Morimasa Ando and Dr. Teruko Kinoshita at the Ando Hospital for the materials of bone-fracture.

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Explanations of photographs

Photo. 1 Roentgenography of the fractured fibula of a person, an arrow showing the wounded part.

Photo. 2 Ditto of another person.

Photo. 3 Ditto, showing in cross section.