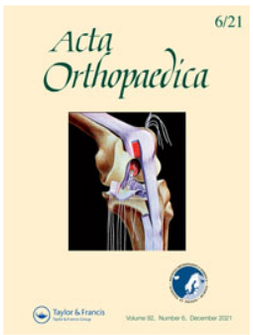

Acta Orthopaedica Scandinavica

ISSN: 0001-6470 (Print) (Online) Journal homepage: informahealthcare.com/journals/iort19

On the Relationship Between Articular Changes and Function

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To cite this article: Ragnar Ekholm & Bengt Norbäck (1951) On the Relationship Between Articular Changes and Function, Acta Orthopaedica Scandinavica, 21:2-4, 81-98, DOI: 10.3109/17453675109024145

To link to this article: https://doi.org/10.3109/17453675109024145

Published online: 08 Jul 2009.

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ON THE RELATIONSHIP BETWEEN ARTICULAR CHANGES AND FUNCTION

By

RAGNAR EKHOLM and BENGT NORBÄCK

INTRODUCTION

The intensified clinical study of joints during recent years has shed light upon the desirability of widening our knowledge concerning the morphology and physiology of joints, and provided impulses for more comprehensive investigations in these fields. The fact is that for several decades articular cartilage has been the main subject of study, while the literature on synovia and synovialis has been rather sparse. With respect to these three articular components, moreover, the reports published so far either do not at all deal with the importance of function, or else they only deal with that functional adaptation which results from prolonged function (months and years). The present paper, on the other hand, is an exposition of some morphological changes that may be observed after brief (minutes and hours), relatively physiological functioning.

LITERATURE

Articular cartilage. Several authors have described the *structure* of articular cartilage at length. It will therefore not be set forth here; the interested reader should consult: Schaffer (1930), Policard (1936), Lubosch (1938), Benninghoff (1922, 1925 a, 1925 b, 1939), Bauer, Ropes and Waine (1940) and Holmdahl and Ingelmark (1948).

While studying the *nutrition* of articular cartilage on amputated animal extremities, Ingelmark and Sääf (1948), observed that intermittent pressure made the cartilage thicker when the marrow cavities of the epiphyses were supplied with "Dextran"[1]. The finding that the thickness of the articular cartilages is capable of rapid variation was

[1] "Dextran" is a solution of polysaccharides of the same molecular weight as the serum proteins manufactured by "Pharmacia", Sweden.

verified roentgenographically by Ingelmark and Ekholm (1948, 1951): By this means the latter authors found that after some minutes of articular function the cartilage grew thicker and that a comparatively short period of rest sufficed to reduce this condition. The only explanation of these variations in thickness is probably that fluid is transported to and from the cartilage.

As long ago as 1894 Hammar stated that normal function of healthy joints undoubtedly has an *abrasive effect* on the surface of the articular cartilage and of the synovial membrane. The same view was later published by Hultén and Gellerstedt (1940), who pointed out that under adequate magnification the surface of a normal articular cartilage is not smooth and even; it is rough, because the outermost cartilaginous layer has been scratched. Hammar's finding of formal elements in normal synovial fluid, probably particles abraded from the cartilages and joint capsule, constitutes further evidence in support of this view.

The synovial membrane. A fairly extensive literature exists on the *structure and function* of the synovial membrane. Full agreement has probably not been reached yet with respect to the character of the cells in it. They have been variously designated as endothelial, epithelial, mesothelial, glandular and modified fibroblastic. In addition the problem whether the synovialis is a complete, continuous membrane without rifts or openings or whether it must be regarded merely as a space in the connective tissue, has given rise to a lively discussion. At present the latter view is dominant. Synopses on the subject with detailed bibliographies have been published by Key (1928 a), Bauer et al. (1940), Davies (1946) and Edlund (1949).

Many methods have been adopted to study the *transport of solutions and particle suspensions* from the joint cavity via the synovial membrane (cf. Edlund 1949). Only a paper by Hultén and Gellerstedt (1940) will be mentioned here. It describes observations of cartilaginous particles in the synovial tissue, where they are in time broken down after injection of finely divided cartilage in fluid suspension into the rabbit knee joint.

The synovial fluid. Discussions on the *nature and origin* of synovial fluid have been carried on for a long time and many theories have been put forward. The opinion generally held today is probably that joint fluid is a dialysate of blood plasma (Ropes, Bennet and Bauer 1939, Bauer, Ropes and Waine 1940, Davies 1946, Sundblad 1950). According to Ropes et al. (1939), this assumption explains all known facts regarding the chemical and physical composition of synovia, except the presence of mucin, albumin and globulin. A simple explana-

tion of the presence of proteins is afforded by the slight protein permeation from the capillaries (Bauer et al. 1940). Where the mucin comes from is not definitely known. Several authors, e.g. Kling (1938), maintain that mucin is a secretory product from the cells of the synovial membrane. They base their opinion on results obtained by metachromatic staining procedures. Davies (1943, 1946), on the other hand, holds that the cells in the synovialis which take metachromic stain are mastcells and consequently have no mucin-producing function. Using Mayer's mucicarmine technique, Cherry and Ghormley (1938) report that they have stained mucin in synovialis cells and from this they conclude that synovial mucin is a product of degeneration. Davies (1943) considers this conclusion faulty. Vaubel (1933), on the other hand, found that a culture of synovialis cells on plasma coagulum showed a marked tendency to liquefy the medium resulting in the production of a mucinoid substance. It is possible, moreover, that the mucin is derived from the periarticular, intercellular connective tissue component (Bauer et al. 1940, Davies 1946).

So far the *quantity* of synovial fluid in various joints has been subjected to very little study. Bauer, Bennet, Marble and Claflin (1930) and Davies (1944) have estimated the amount of synovia in joints of cattle extremities, finding that it varies greatly from animal to animal in the same joint as well as in different joints of the same animal. According to Davies, however, the volumes of articular fluid in corresponding joints of the same animal coincide fairly well. The latter author reports also that the amount of synovial fluid and the animal's weight are positively correlated. By postmortal puncture, Coggeshall, Warren and Bauer (1940) determined the volume of synovial fluid in human knee joints. The values ranged between 0.13 and 2.0 cc and the mean was 0.45 cc.

The first fairly comprehensive study on the *cytology* of synovial fluid was performed by Hammar (1894). Using cattle as experimental animals, several later authors have made similar investigations (Bauer et al. 1930, Warren, Bennet and Bauer 1935, Davies 1945). Others have used rabbits (Key 1926 and 1928, Warren et al. 1935). The cytology of human articular fluid has been studied under normal conditions by Labor and v. Balogh (1919) and Coggeshall et al. (1940).

The results of all these investigations show that the number of cells per c.mm varies widely both from individual to individual in corresponding joints and from joint to joint in the same individual, whereas values from corresponding joints in the same individual are fairly uniform. Most authors are agreed that only nucleated cells occur in normal synovial fluid and that the red blood cells which are some-

times seen must be regarded as artefacts associated with the extraction of the fluid. Differential counts of the nucleated cells vary somewhat in different authors and different experimental series. It is agreed, though, that most of the cells are phagocytes (monocytes, clasmatocytes and undefined nucleated phagocytes) and the rest polymorphonucleated leukocytes, lymphocytes, synovialis cells and unclassified cells. As examples of the number of nucleated cells per c.mm of synovial fluid, it may be mentioned that rabbit joints contain 140-330 (Warren et al.) and human knee joints 13-180 (Coggeshall et al.). Key (1928 b) has seldom seen cartilage cells in the synovia, from which observation he draws the conclusion that frictional wear of the joint capsule wall affects the synovial content of formal elements negligibly. Bauer et al. (1930), however, have observed oval particles which they thought were degenerated cartilaginous fragments.

Both Coggeshall et al. (1940) and Davies (1945) consider it probable that the variability of the cell count is due to differences in the functional state of the joints: increased function should raise the cell content, and the main task of the cells should be to remove the products of abrasion caused by daily joint function.

There exist only few papers on the *viscosity* of synovial fluid, although it is one of the properties most characteristic of synovia. Thus, Schneider (1925) has measured the viscosity of articular fluid from human knee joints and Panizza (1930-1931) did the same with respect to cattle synovia. Both authors obtained very varying values, e.g. for human knee joints 3.9-1490 and for calf radiocarpal joints 8.06-51.18.

Davies (1944) made viscosimetric determinations on a large series of cattle and obtained widely dispersed values (for the knee joint 3.3-575), but the viscosities of synovial fluid from the same animal's corresponding joints tallied well. Davies was unable to find any correlation between volume and viscosity of synovia.

Sundblad (1950) made viscosimeter measurements of synovial fluid from calf, horse and man. His values, like those of earlier authors, varied greatly. The viscosity of fluid samples from essentially normal human knee joints with a mean volume of 0.7 cc ranged from 150 to 300, and in another series with a mean volume of 6.2 cc the values varied between 30 and 150.

According to Blix and Snellman (1945) it is possible, by determining the viscosity at different concentrations of dilute solutions, to extrapolate the limit value for the $\frac{\text{viscosity}}{\text{concentration}}$ quotient at zero concentration. This value, the limiting viscosity, is a constant characteri-

stic of the solute and, provided that the determinations are made under standardized conditions of pH, temperature and salt concentration, it furnishes a relative measure of the molecular length.

Proceeding from this point, Sundblad (1950) emphasizes that a quantitative measure of the degree of polymerisation of the hyaluronic acid may be obtained from viscosity values for articular fluid. The viscosity is related to the length of the hyaluronic acid molecule and goes up sharply as the chain length increases. The viscosity of articular fluid is thus proportional both to the content and the molecular size of the hyaluronic acid component of mucin.

By estimating the hyaluronic acid concentration and the limiting viscosity of normal articular fluid, Sundblad found that the former varies widely while the latter is more or less constant. It follows that the chains of hyaluronic acid molecules have about the same length in different samples of articular fluid. Consequently the high variability of the relative viscosity must be a function of the degree of dilution of normally polymerized hyaluronic acid.

PROBLEMS

The brief review of literature just given reveals that many problems yet remain to be solved with respect to the functional changes in joints. The aim of the present paper is to contribute to the solution of the following problems.

1. Does joint function of short duration and as physiological as possible give rise to histologically observable changes in the articular cartilage?
2. Can cartilaginous or other joint-tissue particles be demonstrated in the synovial membrane after joint function?
3. Are the synovial fluid's volume, formal particle content and viscosity measurably affected by articular function of short duration?

EXPERIMENTAL ANIMALS AND METHODS

The test series comprised adult white rabbits of the same strain, weighing 2.3-3.4 kg. Only the knee joints were studied.

With the aid of a specially designed exercising apparatus (fig. 1), one of the test animal's legs could be made to function without disturbing the other. The exercised animal was anesthetized with 5 cc. per kg body weight of a subcutaneously injected 25 per cent solution of urethane in physiological saline.

The exercised knee joint was subjected to flexing and extending

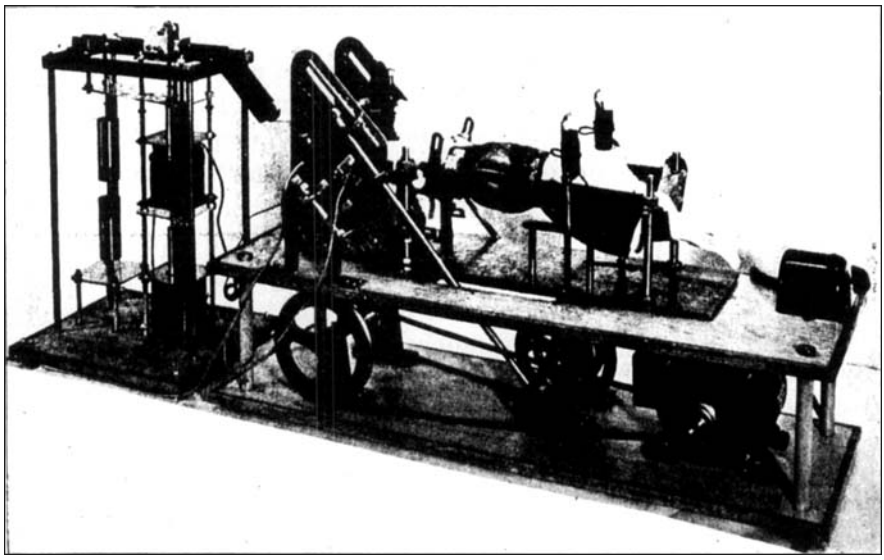

Fig. 1.

Exercising apparatus for rabbit.

movements, the frequency being 90 extensions per minute. A continuous load was applied to the joint surface of some knees by suspending a 400 g. weight in a string attached to a leather cuff around the thigh of the animal. By means of a pulley the load was directed at approximately right angles to the proximal joint surface of the tibia. In another set of animals the leather cuff was linked up with an electromagnet so that the load was applied intermittently during the extension phase of the knee joint. Both these methods, however, involve the possibility of vascular stasis in the thigh. In some animals the load on the joint surfaces was therefore achieved by intermittent innervation of the quadriceps muscle during extension; a 50 cycle alternating current at 13 V and 2 mA was used. In other animals no extra load was applied to the joint. The duration of the exercise varied between 15 minutes and 6 hours and was usually 3 hours. Exercise for several hours probably exceeds physiological limits.

As a rule, immediately after the end of function, the animals were killed by severing the carotids; the hind limbs were amputated for examination of the knee joints.

Three different methods were used to study the *articular cartilages*. Having been excised and divided sagittally, the knee joints from 10 experimental animals were fixed in formalin for 6 days, decalcified under vacuum in 7.5 per cent nitric acid for 10-14 days, and embedded

in paraffin. Sections were stained in Delafield's hematoxylin with eosin as contrast, in toluidine blue solution or gentian violet; they were mounted in Canada Balsam.

The knee joints of 10 other freshly killed animals were opened and by making a tangential incision with a sharp knife pieces of about 5 sq.mm. of cartilage were removed from the loaded parts of the femoral condyles. The pieces of cartilage, all of which extended from top to bottom of the cartilage, were transferred to cattle synovia immediately after removal. Sectioning with a freezing microtome, also in cattle synovia, was performed at once at right angles to the cartilaginous joint surface. The sections were mounted in synovia.

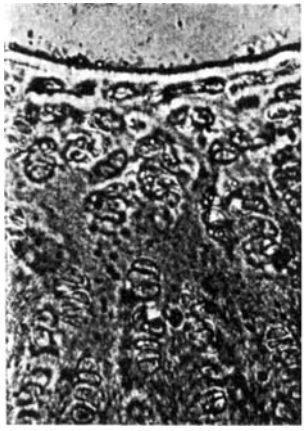

Fig. 2.
Cartilage from exercised joint. Magnified about 400 times. Unstained.

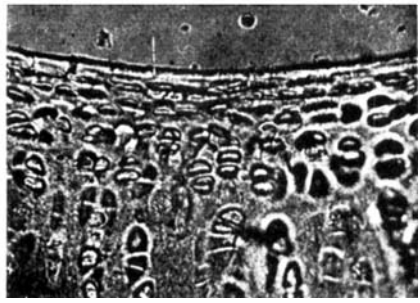

Fig. 3.
Cartilage from rested joint. Magnified about 400 times. Unstained.

In a third group of 20 test animals the knee joints were exarticulated under anesthesia immediately after the exercise was ended. The femurs were quickly amputated and the femoral condyles embedded in carbon dioxide snow. Pieces of cartilage were removed from the femoral condyles as described above, sectioned with a freezing microtome at right angles to the joint surface, mounted in synovia, and at once inspected microscopically.

The synovial membrane was examined both in the decalcified preparations of the intact joints and in excised sections of the rear capsular wall. In the latter cases the preparations were fixed in formalin, embedded in paraffin, sectioned and stained in Delafield's hematoxylin, toluidine blue, or gentian violet.

When the *synovial fluid* was to be studied, the joint cavity was opened by making an incision in the suprapatellar bursa. This incision extended parapatellarly to permit distal reflexion of the patella with its attached quadricipital tendon. Under vigorous flexion of the joint and simultaneous pressure on the dorsal part of the knee as much of the synovial fluid was withdrawn as possible without damaging the synovialis. A micropipette graduated in units of 0.01 cc was used. Thus it was naturally impossible to empty the joint completely, but the removed volume was probably much greater than if a puncture method had been adopted.

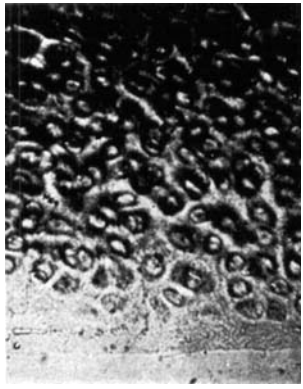

Fig. 4.

Slanted section of cartilage from rested joint. Magnified about 400 times. Unstained.

The extracted joint fluid was stained with a little toluidine blue or gentian violet, or fixed in Müller's fluid, and transferred to a counting chamber (system Buerker). The quantity of formal elements in the synovia was then estimated under the microscope without delay.

We also measured the viscosity of synovia taken from both knee joints of 5 test animals, one of whose legs had been exercised for 30 minutes. The synovia from the exercised joints was collected into one sample and that from the rested joints into another. The samples were analyzed at the Medico-Chemical Institute, University of Uppsala, by Doctor Lars Sundblad.

RESULTS

The number of joints studied is so far too small to yield results such as in all respects permit the drawing of statistically significant,

quantitative conclusions. A number of new, qualitative findings were nevertheless made.

Articular cartilage. Examination of joint cartilage preparations treated by ordinary histological methods brought out no significant difference between the knee joints of the same animal. The remaining two of the above methods, however, revealed microscopic differences between cartilage from the two joints, the observable differences being restricted to the surface layers of the cartilage. Cells so located in cartilage from exercised joints no longer had the flattened form usually exhibited by sections of tissue specimens that are embedded in paraffin. The outermost cells had assumed an ellipsoid shape and those in the next layer were more rounded, sometimes true spheres (fig. 2). Furthermore the cells in the outermost layer from the rested joint (fig. 3) were not quite so flat as the corresponding cells in cartilage specimens that were subjected to standard histological procedures. Anyhow, with a few exceptions, the differences between exercised and rested articular cartilage were clear and could be demonstrated after as little as 15 minutes of exercise, provided that the freezing methods described had been employed.

Synovial membrane. The synovialis from the two knee joints of the same animal exhibited no distinct differences.

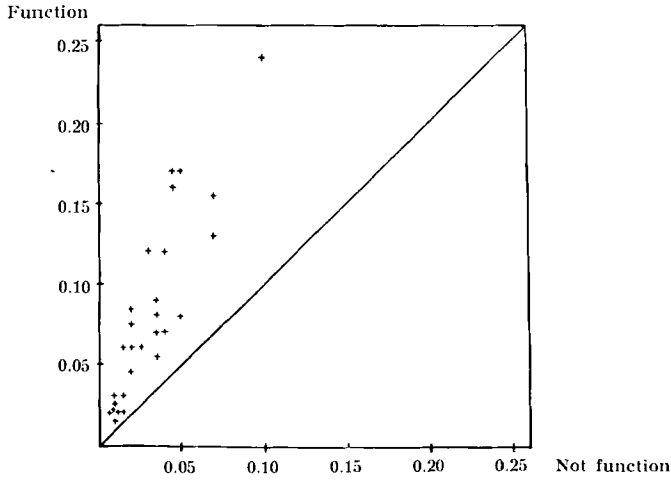

Fig. 5.

Volume in ml. of synovial fluid.

Synovial fluid. The volume of synovia removed from the opened joint cavity with a pipette varied strongly from animal to animal.

The numerical values from all the exercised joints ranged from 0.015 to 0.240 cc, the mean being 0.079 cc. The corresponding values for the contralateral joints were, respectively, 0.008, 0.070 and 0.029 cc. When the two joints of the same animal were compared, however, it turned out that the exercised joint in each animal contained a larger volume of synovial fluid than the rested joint (fig. 5). The proportion between the amount of synovial fluid in knee joints which had been exercised for 0.5-3 hours and that in unexercised knee joints was 2.4 ± 0.16 to 1. The magnitude of this quotient is probably related to the duration of the exercise: the longer the exercise, the higher will be the quotient. The differences, however, are not statistically significant.

All microscopically visible cellular elements in the synovia were counted, except the rarely occurring erythrocytes. Here also the numerical values varied widely. For example, the number of cells per c.mm of synovia from exercised joints ranged from 17-190 and from unexercised joints between 46 and 500. The number of cells per unit volume was in all cases higher in synovia from the rested joint than from the exercised joint of the same animal (fig. 6). However, the total number of cells in the entire volume of synovia from the exercised joint as compared with the cell count for the rested joint shows that the exercise did not significantly affect the cellular content (fig. 7). Between the total number of cells in synovia from an exercised joint and the corresponding quantity for the contralateral joint the quotient is 1.10 ± 0.07.

The synovia contains also formal elements other than cells. The following formations were observed microscopically.

1. Irregular, corned particles, sometimes containing a cellular nucleus that stained bluish-red in toluidine blue and bright red in gentian violet. After being compared with samples of articular cartilage and of joint capsule wall, these particles were examined through a micropolariscope and judged as cartilage particles.

2. Round, homogenous bodies, taking on a fairly intense reddish tone in toluidine blue; they were thought to come from the surface of the synovial membrane.

3. Membranoid pieces of tissue, 50-100 μ long, probably composed of collagenous filaments and coagulated synovial fluid.

4. Granulous bodies coloured reddish by toluidine blue and probably consisting of mucin.

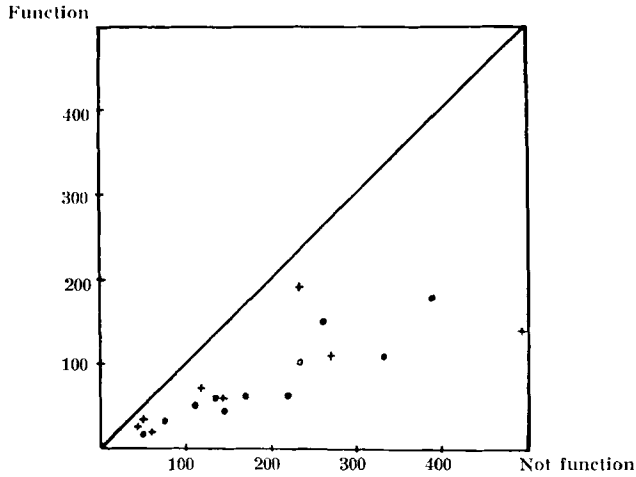

Fig. 6.

Cell count per c. mm. of synovial fluid.

Having a diameter of 10-30 μ, particles of type 1 and 2 were registered quantitatively. Their number per c.mm varied greatly. The cell counts for exercised joints varied between 80 and 350, and for unexercised joints the range was 80 to 570 (fig. 8). Calculated in all the extracted synovia, however, the cell count for the exercised joint consistently exceeded that for the unexercised joint of the same animal (fig. 9). A quotient of 2.2 ± 0.10 between the number of cells in the

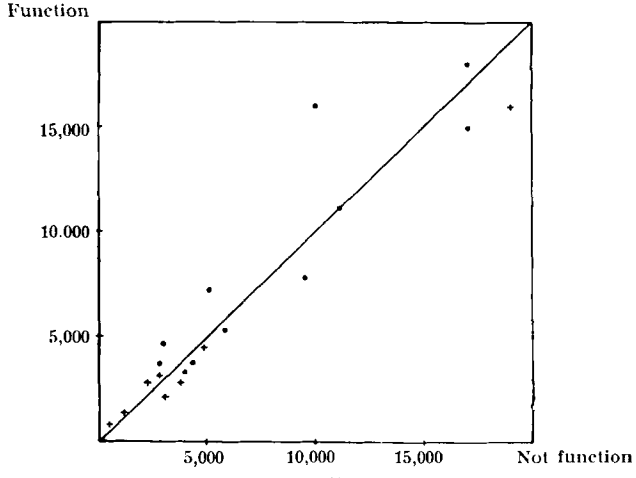

Fig. 7.

Cell count in total volume of synovial fluid.

two joints was obtained by grouping together animals subjected to function for respectively 30 minutes and 3 hours. It seems, however, as though the degree of the increase in the number of particles were dependent on the type as well as on the duration of function: the quotient tended to rise when the joint was loaded in any of the aforementioned ways. Also when the duration of the exercise was prolonged the same tendency was manifest.

Chemical analyses of synovial fluid have shown that exercise causes changes to take place with regard to protein content, hyaluronic acid concentration and viscosity. Thus, the hyaluronic acid concentration in an exercised joint is only about 70 per cent of the corresponding value for a rested joint, and the total protein content shows a similar decrease (the corresponding value is about 65 per cent). The limiting viscosity of synovial fluid, on the other hand, tends to increase during function.

DISCUSSION

Articular cartilage. That the standard histological preparations of articular cartilage from the same animal's corresponding joints, exhibited no differences, even though one joint had been exercised, may seem peculiar. According to Hammar (1894) and Hultén and Gellerstedt (1940), loosening or signs of abrasion should have been exhibited by the outermost layer of articular cartilage. The reason why such signs were absent might be that the less sensitive histological method would have obliterated them. Another explanation may be that any abrading processes involve only a small area of the joint surface which, consequently, would stand small chance of being included in sections cut at right angles to them. Actually, the area of all the cartilaginous particles observed in the synovia totalled at most 1/1,000 of the joint area. Obviously, however, the above reasoning is rather uncertain.

As mentioned in the review of literature, earlier investigations have shown that function causes the articular cartilage to swell (cf. Ingelmark and Sääf 1948, Ingelmark and Ekholm 1948 and 1951). Recently published investigations (Ekholm 1951), involving the use of radioactive gold, bear out the assumption that function augments the flow of fluid to the cartilage. The alteration in the superficial cell shapes of the articular cartilages observed in the present investigation is probably at least one histological manifestation of such an inflow of fluid.

We do not know the cause of the change of cell-shape but two possibilities may be mentioned here: it appears that the change of the

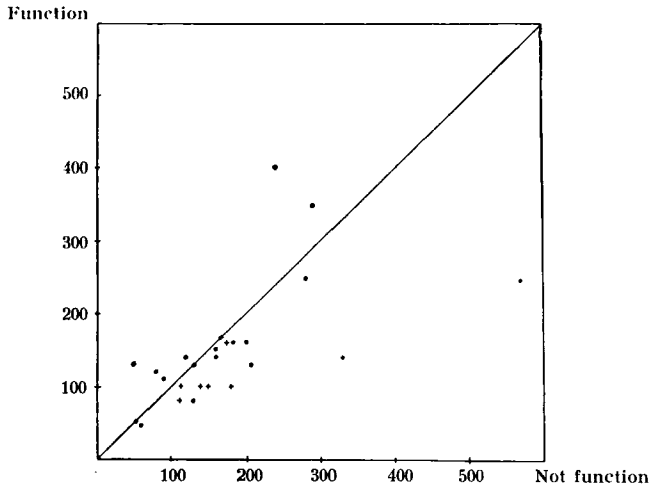

Fig. 8.

Number of abraded particles per c. mm. of synovial fluid.

cellular shape may be due to an increase of the water content of the cells. It is also possible, however, that the increase of he cartilage volume that takes place owing to the inflow of fluid, causes a change in the arrangement of the collagenous filaments and that this change modifies the shape of the superficial cells.

It should be noted, however, that not all the sections showed the

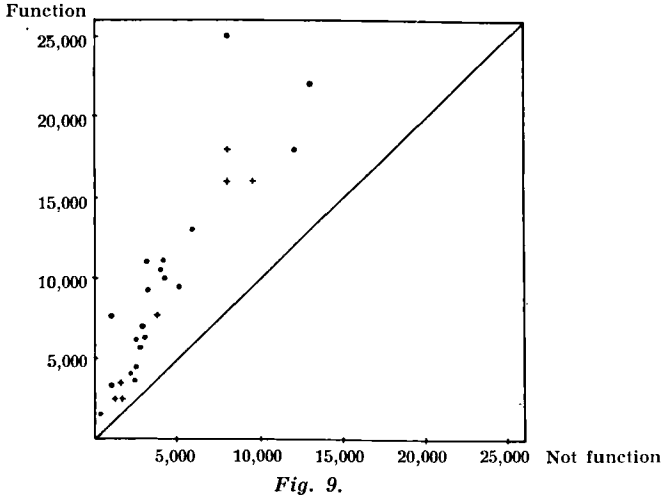

Fig. 9.

Number of abraded particles in total volume of synovia.

previously mentioned cellular deformation, one of the reasons being that sections perpendicular to the cartilage surface are necessary for correct evaluation of the microscopic picture. Obliquely sectioned, every articular cartilage can yield pictures that bear some likeness to upright sections from exercised joints. Oblique sections may be distinguished from perpendicular sections, however, by examining the cellular architecture in the sub-surface cartilaginous layers. It will then be seen that the former type of section does not have the characteristic columnar arrangement (fig. 4).

The shorter the interval between the removal of the cartilage from the bone and the histological examination, the more distinct become the differences between the superficial layers of articular cartilage in the exercised and the contralateral joint. This factor is highly important since in the exercised cartilage the cellular shape is restored quite quickly—although mounting in cattle synovia on the whole provides a physiological environment for rabbit cartilage—and it tallies well with the results of roentgenographic studies on variations in the thickness of articular cartilages (Ingelmark and Ekholm 1948 and 1950). A considerable reduction in thickness was observed by these authors as little as 30 minutes after the exercise.

In order to ensure that the sections were examined as objectively as possible a large number from the two joints were inspected under the microscope without previous discrimination. Only very rarely was it difficult to determine whether the cartilage section under observation came from an exercised or from an unexercised joint.

The synovial membrane. It is difficult indeed in histological sections to judge the surface of the synovial membrane. The absence on it of definite defects or abrasive phenomena was therefore not surprising. The deposition of cartilaginous fragments in the synovial membrane and its cellular reaction to large amounts of foreign cartilage, as reported by Hultén and Gellerstedt (1940), was not visible with our rather more delicate procedure. It is probable, however, that the period of observation (3 hours) was altogether too short for such changes to manifest themselves.

The synovial fluid. As stated in a preceeding chapter, the numerical values for both the volume and the content of cells and abraded particles in the synovia showed marked variations. The same observation was made by earlier authors. However, despite the great variations, the volume of synovia was consistently higher in the exercised than in the unexercised joint. The volume increase was not accompanied by a corresponding increase of the total cell content and the relative visco-

sity, and the percentage of protein decreased in the exercised as compared with the rested joint. These three observations undoubtedly indicate that physiological joint function is attended by dilution of the synovial fluid, i.e. admixture of it mainly with water and dissolved low molecular substances. The assumption is thus confirmed that synovia is composed chiefly of a plasma dialysate, because articular function is associated with an increased flow of blood through the joint tissues.

Whether the raised water content of the synovia comes exclusively from vessels in the joint capsule or whether it is partly due to a flow of more fluid from the marrow cavity through the articular cartilage is not yet known.

It is probably no easy matter to offer a teleological explanation of the dilution of synovial fluid in connection with function; for it would seem partly that the small volume of synovia in a resting joint is ample for lubricating purposes and partly that this lubricating action of the synovia is reduced by the lower viscosity resulting from dilution. The greater volume of the synovia may perhaps be of nutritional significance to the articular cartilage, provided that its nutrition mainly takes place via the synovial fluid.

The higher rate of frequency of the previously described particles of type 1 and 2 can with some degree of probability be attributed only to wear of the walls of the joint cavity. Differential counting of the two types of particles was performed in a few cases only. It would seem as though about 30 per cent of the particles were fragments of articular cartilage.

As surface wear of the articular cartilages thus definitely takes place concurrently with joint function within normal limits, we are very probably justified in reckoning on a continuous regeneration of the superficial layers of cartilage. Naturally the present investigation cannot provide any information on how the regeneration is accomplished.

SUMMARY

A comparative physiological method of exercising the rabbit knee joint is described.

A new method is given for histological examination of articular cartilage; this method, according to the authors, is superior to standard procedures in providing a picture of articular cartilage that corresponds better with intravital conditions.

It was possible to show that, after brief function, the surface cells of articular cartilage are more spherical than the corresponding cells of non-exercised cartilage. This transformation was assumed to be due to increasing accumulation of fluid in the cartilage during exercise.

Function is attended by an increase in volume of the synovial fluid.

The number of cells per c.mm of joint fluid is lower after function; but a cell count in all the synovia in the joint reveals that the total number of cells remains unchanged.

The percentages of protein and hyaluronic acid in synovial fluid are diminished by articular function. Hence, from the constant total cell count, the conclusion may be drawn that the increase in synovia volume attendant upon exercise is chiefly due to the inflow into the joint cavity of water and dissolved low-molecular substances.

The joint fluid contains particles which, in the authors' opinion, are derived partly from the surface of the articular cartilage and partly from the inside of the synovial membrane. The number of these particles is larger in the exercised joint than in the rested joint. Physiological function would thus seem to be associated with abrasion both of the articular cartilage and of the synovialis.

RESUME

Description d'une fonction physiologique relative de l'articulation du genou chez les lapins.

Une nouvelle méthode d'examen histologique du cartilage articulaire est indiquée. D'après l'auteur, c'est une méthode supérieure à la technique histologique ordinaire du fait qu'elle donne une image du cartilage articulaire qui concorde à un plus haut degré avec le rapport intravital.

Il a pu être démontré qu'en liaison avec une courte fonction, les cellules superficielles du cartilage articulaire prennent une forme plus sphérique que les cellules correspondantes du cartilage au repos. On suppose que cette modification de forme est due à une plus forte absorption de liquide dans le cartilage durant la fonction articulaire.

Sous l'influence de la fonction, le volume de la synovie augmente.

Le nombre des cellules au mm^3 de liquide articulaire est réduit en cours de fonction. Par contre, si l'on compte les cellules dans tout le volume de la synovie de l'articulation, on constate que leur nombre global est resté inchangé.

La teneur en albumine et en acide hyaluronique de la synovie diminue en liaison avec la fonction articulaire. On conclut de ce fait et aussi du fait que le nombre des cellules reste constant que l'augmen-

tation du volume de la synovie en cours de fonction est la conséquence d'un apport d'eau, notamment, et de substances moléculaires basses libres.

Le liquide articulaire contient des particules qui, de l'avis des auteurs, proviennent en partie de la couche superficielle du cartilage articulaire, en partie de la surface intérieure de la membrane synoviale. Le nombre de ces particules est plus élevé dans l'articulation qui est en fonction que dans celle qui est au repos. La fonction physiologique entraînerait ainsi une usure aussi bien du cartilage articulaire que de la synovie.

ZUSAMMENFASSUNG

Eine Methode der relativ physiologischen Funktion des Kniegelenkes vom Kaninchen wurde beschrieben.

Eine neue Methode der histologischen Untersuchung von Gelenksknorpel wurde angegeben. Nach der Meinung des Verfassers ist diese Methode der gebräuchlichen histologischen Technik insofern überlegen, als sie ein Bild des Gelenksknorpels gibt, das in höherem Grade mit dessen Verhalten beim Lebenden übereinstimmt.

Man konnte nachweisen, dass im Zusammenhang mit einer kurzdauernden Funktion die Oberfächenzellen des Gelenksknorpels eine mehr spherische Form aufweisen als die entsprechenden Zellen im ruhenden Knorpel. Diese Formveränderung steht vermutlich im Zusammenhang mit einer vermehrten Flüssigkeitsaufnahme des Knorpels während der Gelenksfunktion.

Im Zusammenhang mit der Gelenksfunktion steigt das Volumen der Synovia.

Die Zahl der Zellen per mm^3 Gelenksflüssigkeit sinkt bei Funktion. Berechnet man hingegen die Zellenanzahl für das gesammte Synoviavolumen der Gelenke, dann zeigt es sich, dass die Gesammtanzahl der Zellen nicht verändert wird.

Der Eiweiss- und Hyaluronsäuregehalt der Synovia sinkt im Zusammenhang mit der Gelenksfunktion. Aus diesem Verhalten, zusammen mit der konstanten Gesammtanzahl der Zellen, zieht man den Schluss, dass die Vermehrung des Synoviavolumens während der Funktion in der Hauptsache eine Folge von Einströmung von Wasser und gelöster, niedrig-molekulärer Substanzen ist.

Die Gelenksflüssigkeit enthält Teilchen die gemäss der Auffassung der Verfasser teils von der Oberflächenschicht des Gelenksknorpels, teils von der inneren Oberfäche der Synovialmembran herstammen. Die Zahl dieser Teilchen ist grösser in einem funktionierenden als in

einem ruhenden Gelenk. Deshalb dürfte die physiologische Funktion einen Verbrauch, sowohl des Gelenksknorpels als auch der Synovialis, mit sich führen.

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