FIEP-BULLETIN

"EDUCATION PHYSIQUE ET LA SCIENCE"

de la Fédération Internationale d'Education Physique (FIEP)

2 1957

27e Année

RÉDACTION

Rédacteur responsable: Dr. Med. h.c. Major J. G. Thulin, Sandgatan 14, Lund, Suède. Tel. 105 15.
Rédacteur: Major Osvald Kragh, Linnégatan 8 d, Lund, Suède. Tel. 122 30.
Secrétaire: Mme Ann-Mari Ivarsson, Sandgatan 14, Lund, Suède.

Pour la *Section Scientifique:* Dr. Erling Asmussen, Gymn.-theor. Laboratorium, l'Université de Copenhague, Danemark.
Pour la *Section Scolaire:* Gymn. dir. Capitaine Klas Thoresson, Gymn. Centr. Inst., Stockholm, Suède.
Pour la *Section Récréative:* Gymn. dir. O. Kihlmark, Administrateur de Svenska Gymn.-förb., Kungsholmstorg 6, Stockholm, Suède.

ENQUÊTE

11. La Gimnasia adaptada al medio escolar: algunas consideraciones fundamentales

por MICHEL BOTTU, Bélgica

Continuación de Bulletin 1/1957

Generalmente, ya no se discute la necesidad de actividades físicas en el medio escolar. Por otra parte, el carácter de urgencia que hoy las pone de relieve, se debe por una parte al ritmo de la vida moderna y por otra al aumento de la vida sedentaria causado por el constante progreso técnico.

La educación física[1] es la llamada a restablecer el equilibrio amenazado por una concepción de la educación excesivamente intelectualista.

Es indispensable para restablecar el equilibrio físico y la acuidad sensorial del niño y del adolescente sin lo cual el desarrollo intelectual y el florecimiento de la personalidad se verían comprometidos. Entre las actividades físicas utilizadas para los escolares, como medios de formación, las técnicas gimnásticas son fundamentales y esenciales.

Las aplicaciones gimnásticas en el medio escolar, deben necesariamente basarse sobre normas fisiológicas, psicológicas y pedagógicas.

Los conocimientos adquiridos sobre el crecimiento, el desarrollo de las aptitudes motriceslas características de las etapas del crecimiento, la evolución del interés, son las determinantes de la elección de los medios técnicos y de su aplicación en el medio escolar.

Si consideramos la escolaridad en su totalidad, desde el jardín de la infancia hasta la Universidad, pasando por la enseñanza primaria y media, vemos que los grandes períodos de crecimiento llamados mediana y gran niñez, los períodos de la pre-pubertad, de la pubertad y de la pos-pubertad caracterizan la evolución biológica del niño y del adolescente. Aún estando de acuerdo en que es prácticamente imposible conseguir en las clases una homogeniedad ideal, debemos admitir que a esos períodos de crecimiento corresponden, en una medida muy grande, edades cronológicas. Por lo tanto es posible adaptarla técnica gimnástica a esas edades, teniendo en cuenta las particularidades propias a los diferentes períodos del crecimiento.

Los medios empleados en Educación Física escolar deben adaptarse no solamente a la edad, sino también a la mentalidad correspondiente a esa edad. De ello resulta que los ejercicios de gimnasia que se utilicen no deben corresponder solamente a las posibilidades somáticas y a la evolución morfológica del niño o del adolescente, sino también a las

[1] Por «Educación Física» designamos el conjunto de medios que ponen en juego el aparato locomotor y utilizan las funciones motrices bajo diferentes formas tales como las actividades gimnásticas, el juego o los ejercicios deportivos.

Sw. Cr. 2: 50 — Engl. sh. 3/9 — U.S.A. $

exijencias de su desenvolvimiento mental de sus aptitudes psico-motrices y de su interés. Esta adaptación a la evolución general del niño y del adolescente debe continuarse en el tiempo.

De éste principio dimanan algunas sugestiones prácticas. Durante el período conocido por mediana infancia (de 4 a 7 años), toda la educación física del niño debe llenar su necesidad natural de movimiento y satisfacer su alegría así como su fantasía tan notable a esa edad. Una gimnasia sistemática, no le conviene.

En el período llamado gran niñez (de 8 a 12 años), la mentalidad del niño, se ha modificado ya. El género de gimnasia que fué bueno en el grado precedente, no conviene por demasiado pueril a los niños de 8 a 10 años. Sin embargo una gimnasia excesivamente austera que no tiene en cuenta «el interés», factor esencial en la actividad del niño está también llamada al fracaso. Ni la gimnasia sistemática, ni aquella propia a los niños de 4 a 7 años son adaptables a éste período. Solamente hacia la edad de 10 años empieza el niño a utilizar las funciones necesarias para llegar al pensamiento abstracto, es cuando empieza a juzgar lo que vé y lo que oye, a asimilar las explicaciones que se le dán, a ejercitar su sentido crítico y a razonar, emtonces podrá influirse sobre su crecimiento con una gimnasia sistemática.

En el período de la pre-pubertad, debe ser abolido todo lo que signifique el empleo exajerado de la fuerza que vaya más allá de la resistencia funcional del alumno. La capacidad de trabajo del joven es efectivamente más bien debil. Hay que cansarlo mediante ejercicios apropriados que favorezcan el crecimiento normal en altura. Pero a causa de la fragilidad de las articulaciones a esa edad, el alumno ha de practicar los saltos con prudencia. Destaquemos, sin embargo que los ejercicios de saltos y de agilidad favorecen las reacciones psico-motrices. Los juegos con tendencias emuladoras así como los juegos de lucha, pueden satisfacer las tendencias combativas de los niños. Sin duda puede admitirse el aprendizaje de las técnicas deportivas, sin que a pesar de ello las competiciones deportivas se incorporen a los programas valederos para éste período.

Por el contrario, la fase de la pubertad descubre notables posibilidades de desarrollo así como el gusto de la selección. Ciertamente que las perturbaciones inherentes a esa época del crecimiento, se manifiestan también en gimnasia y exigen una adaptación prudente a las fuerzas musculares y orgánicas y a su valor funcional. Una adaptación prograsiva influirá favorablemente sobre el desarrollo de la firmeza, de la confianza en sí mismo, de la decisión y de la audacia.

En el período de la pos-pubertad tanto el joven como la joven son potencialmente adultos. Poseidos de una vitalidad que empieza, el deseo de su desarrollo muscular y la prueba de su resistencia orgánica son completamente normales. Además se van manifestando, tendencias hacia la especialización. Una gimnasia en la cual no sobresaliera el trabajo de aplicación, no interesaría.

Pasado éste período, la educación física debe orientarse hacia la consecución de una condición física requerida por la práctica del ejercicio gimnástico con caracteres deportivos, con el fin de que florezcan todas las posibilidades, tanto físicas como morales.

Añadamos a todo esto que hay que evitarle al niño y al adolescente ejercicios que lo fatiguen fisicamente o lo aburran psiquicamente.

El ejercicio dinámico debe preferirse al trabajo muscular estático y la modalidad de ejecución de los ejercicios debe tenerse en cuenta. En cuanto a los efectos correctivos de la gimnasia en el medio escolar de ninguna manera deben perderse de vista para una compostura correcta. Vista su importancia desde el punto de vista morfológico serán los inspiradores de la técnica. Una gimnasia no es realmente correctiva sino cuando la técnica que la inspira es irreprochable desde el punto de vista corrección.

La diferencias morfológicas entre los dos sexos así como ciertas consideraciones de orden fisiológico y psíquico constituyen indicaciones preciosas desde el punto de vista de la modalidad de aplicación a la joven de los medios de educación física.

19. Bases Sobre las Cuales Asentar la Educación Física Escolar

Por Adolfo Pérez Acosta
Prof. de Educación Física en el Departamento Federal de Educación Física y Deportes del Ingenio del Mante, Tamps., México

La Educación Física es tan antigua como la civilización misma, y sus necesidades, siempre en relación al progreso de esta aún no han sido definida totalmento. — Día a día la Educación Física está tomando caracteres importantes como medio de mejoramiento individual y colectivo entre los pueblos civilizados; por lo que, organizaciones e instituciones con sus médicos y pedagogos entre su personal, se preocupan constantemente de la importancia que reviste el tema.

Creo que, en todas las escuelas primarias o elementales y en casi la totalidad de los paises, siempre se ha tropezado con inconvenientes de carácter pedagógico para las clases de Educación Física en general y de gimnasia en particular, base principal de la primera; por lo que será dificil creer que podamos conseguir pronto o de inmediato un resultado satisfactorio; pero no por ello dejémonos llevar por el pesimismo y hacer aún más difícil la situación y finalidad de la Educación Física. — Es necesario insistir que la Educación Física, para ser efectiva, necesita el que se la conseda el rango de cualquier otra enseñanza, porque incluso, las demás disciplinas necesitan para su efectividad en los niños, encontrar una base corporal sólida, sin lo cual sería inútil todo esfuerzo; dotarla de locales apropiados y demás necesidades, pero, mientras esta oportunidad se presenta será necesario hacer frente a las necesidades actuales con los materiales existentes aún cuando estos resulten insuficientes. —

No ha y ni será posible nunca unificar los métodos de Educación Física existentes en el mundo por existir grandes diferencias entre los niños de un pais a otro, inclusive en una nación, en una región de esta y todavía más, en una misma escuela; por lo que es necesario establecer normas metodològicas para grupos determinados también en esta última tomando en consideración las condiciones fisiológicas de los niños. —

En México, la Dirección General de Educación Física con la cooperación del Instituto Nacional de Pedagogía de la Secretaría de Educación Pública, ha establecido que, las clases de Educación Física se lleven a cabo bajo una clasificación que es el resultado del Indice de Robustez o de Equilibrio Morfológico (I. E. M.=PR+PT (100), Indice de Equilibrio Morfológico es igual al Peso Real divido entre el Peso Teórico, multiplicado por 100. — Esto permite elaborar para cada grupo una serie de ejercicios distintos, ya que cada uno de ellos es completamente distinto: *Hipernutridos, nutricion optima, nutricion media, desnutricion, desnutricion avanzada.*

La clasificación anterior, tiene entre otros motivos el que el profesor no se limite a enseñar los mismos ejercicios en calidad y cantidad a todos los niños a su cuidado, ya que como se verá los ejercicios correspondientes a las clasificaciones de los extremos merecen una atención especial, por lo que, aparte de favorecer desde el punto de vista fisiológico a los educandos, se estimula la necesidad de una mayor preparación del educadór. —

Una cosa por el estilo, proporciona a quien lo lleva a cabo poder hacer mediciones periódicas y palpar el adelanto, estancamiento retroceso de los que se educan físicamente.

Todo lo anterior, unido a unas cuantas horas más de trabajo por semana considero daría mejores resultados.

Los fines de la Educación Física, salud mental, salud física, adaptación social, influencia sobre el carácter y la volundad etc. etc., tienen que conseguirse haciendo buen uso de sus múltiples medios de que dispone y que bien podrían adaptarse a las necesidades ambientales existentes.

Los Deportes, como el Volleyball, Softball, Unigol para niños de ambos sexos y Basketball y algunas pruebas de atletismo para los niños varones, podrían servir muy bien como complemento de la Educación Física, sin darle desde luego la importancia que despiertan por el estímulo de la emoción; cosa muy difícil ya que el niño acepta el juego sin mas condición que la emotividad que lo mueve y que puede servir o mejor dicho sirve como un escape a la gimnasia que está movida por el razonamiento. — Debe seguirse siempre en todo esto un fin pedagógico, fisiológico y social.

The Basis on which to build the Physical Education of School Children

By Adolfo P. Acosta

Physical education is as old as civilization itself and its needs are always related to the progress of the latter, although they are not yet totally defined. Day by day physical education is becoming more important as a means of improvement both individually and collectively in the civilized world. This is the reason why organizations and institutions with physicians and pedagogues on their staff are all busily engaged with this important matter.

I believe that in all primary schools and elementary schools in the majority of countries pedagogical difficulties have arisen in all kinds of physical education in general and in gymnastics in particular, and for this very reason it seems difficult to imagine that in a short time a solution can be reached, which will be satisfactory to all. But we must not give in to pessimism, and thus further complicate our situation and cause us to loose sight of the aim of physical education.

It is necessary to insist that physical education, in order to be effective, should be given the same rank and value as the other subjects, since the other subjects, in order to be more effective, must build on a solid physical basis, since without this basis all efforts would be in vain. It is therefore necessary to get better playing fields, gymnasiums and other necessities, but until this is realized, we must try to overcome our present difficulties by using that material even though it be insufficient, which is at hand.

It is not possible and will never be possible to unite the existing methods of physical education, since there are such great differences between children in different countries or even in a country or again within a region of a country or finally within the same school. For this reason it is necessary to establish methodic norms, in which one must take into consideration the physiological condition of the children.

In Mexico the General Committee for Physical Education with the cooperation of the National Institute of Pedagogy has arranged the matter in the following way: the physical education classes are divided in a certain way, which is the result of the "Indice de Robustez o de Equilibrio Morfologico" (Index of Robustness), where the latter is equivalent to the net weight divided by the normal theoretical weight multiplied by 100. This allows the working out for each group of a series of different exercises, since each group is quite different: overfed, ideally fed, mediumly fed, underfed and extremely underfed.

The above classification is motivated by the fact that the teacher does not restrict himself to the teaching of the same exercises to all children, since as we shall see those exercises, which belong to the extreme classifications must be afforded special attention, and as a result, apart from the fact that they are advantageous to the children from a physiological point of view, they act as a stimulation to the teacher to prepare his lessons.

The teacher should regularly control the weight of the children and follow carefully any changes in their development.

The above, which of course means a few extra hours' work for the teacher, will in my opinion produce a good result.

The aims of physical education (mental health, physical health and social adaption, influence on character and will, etc.), will succeed, provided that one uses all the numerous means, which one has at ones disposal and that one is able to adapt oneself to the existing conditions.

Games, such as volley ball, softball etc. for children of both sexes, and basket ball and some athletic exercises for boys, may well serve as a complement to physical education, but of course without their being given the importance, which is awakened by emotional stimulance; a point which is very difficult, since the child simply accepts the game, which appeals to it and which can serve as a means of refuge.

One must always have the pedagogical, physiological and sociological ends in view.

20. Las bases sobre las cuales asentar la cultura fisica escular

por Prof. Antonio Estopier Estopier
Director General de Educación Física, México, D. F.

Además, hace una consulta acerca de nuestra opinión sobre «Cómo encontrar las bases sobre las cuales construír la Educación Física de las escuelas para niños». Acerca de esta cuestión, hemos tomado como base las normas desprendidas del concepto Bio-Psico-Socio-Filosófico de la Educación Física, aprobado por el Congreso Panamericano de esta especialidad, efectuado en esta ciudad en octubre de 1948, con el agregado de que la Educación Física no es una parte sino un factor de la Educación Integral.

Aun cuando nuestros medios no son tan vastos como deseamos, procuramos no omitir ninguno de los siguientes aspectos que consideramos necesarios para una educación física que de verdad coadyuve a la educación integral del individuo; dosificando el esfuerzo que se pide al alumno, de acuerdo con las condiciones que presenta:

1. — Clasificación de los alumnos (por su estado nutricional; en categorías deportivas y por el grado de desarrollo — sexual que alcanzan).
2. — Ejercicios de order, control o disciplina.
3. — Gimnasia funcional.
4. — Actividades rítmicas.
5. — Juegos.
6. — Deportes.
7. — Excursionismo.

Cada uno de estos puntos, con excepción del primero, se desarrolla con mayor o menor intensidad, según las condiciones especiales de la localidad, de la escuela o del grupo, dando el matiz adecuado a las facilidades y las necesidades que se encuentren.

Aunque no creemos haber logrado las normas perfectas, pensamos que el camino a seguir es la naturaleza misma del individuo, cuyas características deben someterse a un perfeccionamiento que on provoque daños de ningún género, sino antes bien, que encauce los valores hacia la meta del sano bienestar personal y colectivo.

Anexo a usted algo del material didáctico que se elabora en esta Dirección, gue espero de le idea de cómo tratamos de llegar a nuestra meta.

Extracto del

Plan General de Trabajo, año de 1957

Secretaría de Educación Pública, Dirección General de Educación Física, México

Consideraciones fundamentales.

1ra. — Considerando que la Educación Física, en su concepto Bio-Psico-Socio-Filosófico, es un factor determinante de la Educación Integral del ser humano como agente de progreso y de bienestar social.

2a. — Considerando que la Dirección General de Educación Física es el Organismo Oficial en quién el Gobierno de la República ha depositado legalmente la responsabilidad de planear, orientar, organizar, dirigir, encauzar, coordinar, realizar y supervisar la labor de la Educación Física Nacional, en los diferentes Sectores de Población.

3ra. — Considerando que la política del Régimen actual, tiende a que los Organismos Oficiales se conviertan en Instituciones de Servicio Social en las que imperen el espíritu de trabajo y de responsabilidad funcional, la honestidad, la respectabilidad de los derechos legal y humanitariamente establecidos, las normas disciplinarias más conscientes y bustness), where the latter is equivalent to the net weight divided by the normal theoretical weight multiplied by 100. This allows the working out for each group of a series of different exercises, since each group is quite different: overfed, ideally fed, mediumly fed, underfed and extremely underfed.

The above classification is motivated by the fact that the teacher does not restrict himself to the teaching of the same exercises to all children, since as we shall see those exercises, which belong to the extreme classifications must be afforded special attention, and as a result, apart from the fact that they are advantageous to the children from a physiological point of view, they act as a stimulation to the teacher to prepare his lessons.

The teacher should regularly control the weight of the children and follow carefully any changes in their development.

The above, which of course means a few extra hours' work for the teacher, will in my opinion produce a good result.

The aims of physical education (mental health, physical health and social adaption, influence on character and will, etc.), will succeed, provided that one uses all the numerous means, which one has at ones disposal and that one is able to adapt oneself to the existing conditions.

Games, such as volley ball, softball etc. for children of both sexes, and basket ball and some athletic exercises for boys, may well serve as a complement to physical education, but of course without their being given the importance, which is awakened by emotional stimulance; a point which is very difficult, since the child simply accepts the game, which appeals to it and which can serve as a means of refuge.

One must always have the pedagogical, physiological and sociological ends in view.

20. Las bases sobre las cuales asentar la cultura fisica escular

por Prof. ANTONIO ESTOPIER ESTOPIER
Director General de Educación Física, México, D. F.

Además, hace una consulta acerca de nuestra opinión sobre «Cómo encontrar las bases sobre las cuales construír la Educación Física de las escuelas para niños». Acerca de esta cuestión, hemos tomado como base las normas desprendidas del concepto Bio-Psico-Socio-Filosófico de la Educación Física, aprobado por el Congreso Panamericano de esta especialidad, efectuado en esta ciudad en octubre de 1948, con el agregado de que la Educación Física no es una parte sino un factor de la Educación Integral.

Aun cuando nuestros medios no son tan vastos como deseamos, procuramos no omitir ninguno de los siguientes aspectos que consideramos necesarios para una educación física que de verdad coadyuve a la educación integral del individuo; dosificando el esfuerzo que se pide al alumno, de acuerdo con las condiciones que presenta:

1. — Clasificación de los alumnos (por su estado nutricional; en categorías deportivas y por el grado de desarrollo — sexual que alcanzan).
2. — Ejercicios de order, control o disciplina.
3. — Gimnasia funcional.
4. — Actividades rítmicas.
5. — Juegos.
6. — Deportes.
7. — Excursionismo.

Cada uno de estos puntos, con excepción del primero, se desarrolla con mayor o menor intensidad, según las condiciones especiales de la localidad, de la escuela o del grupo, dando el matiz adecuado a las facilidades y las necesidades que se encuentren.

Aunque no creemos haber logrado las normas perfectas, pensamos que el camino a seguir es la naturaleza misma del individuo, cuyas características deben someterse a un perfeccionamiento que on provoque daños de ningún género, sino antes bien, que encauce los valores hacia la meta del sano bienestar personal y colectivo.

Anexo a usted algo del material didáctico que se elabora en esta Dirección, gue espero de le idea de cómo tratamos de llegar a nuestra meta.

Extracto del

Plan General de Trabajo, año de 1957

Secretaría de Educación Pública, Dirección General de Educación Física, México

Consideraciones fundamentales.

1ra. — Considerando que la Educación Física, en su concepto Bio-Psico-Socio-Filosófico, es un factor determinante de la Educación Integral del ser humano como agente de progreso y de bienestar social.

2a. — Considerando que la Dirección General de Educación Física es el Organismo Oficial en quién el Gobierno de la República ha depositado legalmente la responsabilidad de planear, orientar, organizar, dirigir, encauzar, coordinar, realizar y supervisar la labor de la Educación Física Nacional, en los diferentes Sectores de Población.

3ra. — Considerando que la política del Régimen actual, tiende a que los Organismos Oficiales se conviertan en Instituciones de Servicio Social en las que imperen el espíritu de trabajo y de responsabilidad funcional, la honestidad, la respectabilidad de los derechos legal y humanitariamente establecidos, las normas disciplinarias más conscientes y

DE LA SECTION SCIENTIFIQUE

Morpho-Physiological Aspects of Gymnastic Exercises

By Prof. Dr. BO E. INGELMARK
Prof. University of Gothenburg, Sweden. Institute of Anatomy.

Since long ago the intimate correlation between the structure and the size of the muscles on one hand and their function on the other is very well known. Contrary to this similar correlations concerning the other parts of the locomotion organs, for instance bones, cartilages, and tendons have not been much observed in older days. Modern scientific investigations, however, have been done of these problems rather thoroughly. The new results, so obtained, are of importance for the physical training, and therefore I want to give you a short review of those questions.

We shall begin with the connective tissue as the most primitive one, and as that which is, from a genetic point of view, the origin of other parts of the locomotion organs. From a mechanical view-point, the connective tissue with its collagenous and elastic fibres is the most important part of those organs, which command the statics of the human body. If the functional strains increase in such a tissue, the number of cells per unit of volume will increase too. After some time the intercellular component, that is the collagenous and elastic fibres with their ground substance, will begin to hypertrophy. This creation of intercellular substance will later be so excessive that the number of cells per unit of volume will decrease. In order to demonstrate this process I should like to show you some lantarn slides.

The first one shows the number of cells per unit of volume in the tendons of the biceps muscle of the arm and the semitendineous muscle of the thigh at various ages. As you see, in childhood there are very high values which decreases gradually at higher ages. The next slide demonstrates the cross section area of those tendons from the same material. Here you can see that the curves rise from low values in newborn up to the definite value at about 20 years of age. If we are studying those two curves together, that means the total number of cells in all the tendons, we get the next figure. From the beginning of the childhood the curves rise to about 7 years of age and after that, they fall gradually.

The same results can be seen in animals studied under different degrees of training and at various ages.

The hypertrophy of the intercellular substance of connective tissue will give an increase of the volume of tendons, respectively ligaments, and of their total tensile strength. This strength per unit of the cross section area will increase too. It is of very great importance to observe the submicroscopical collagenous fibrils in tendons from an animal, which has been trained previously. Studied in the electronic microscope they show a higher breadth and another type of cross-striation than fibrils from untrained animals. This means that the training is of importance not only for the macroscopical formation of those organs but also for the smallest units of this kind of tissue.

The examples just demonstrated are taken from human and animal tendons. Between the ligaments and the tendons there are small differences only. Their structure is essentially the same. Therefore, I mean, we are entitled to conclude that the ligaments have the same functional adaptability as those of the tendons.

It is of interest to note that the hypertrophy of a tendon during training is just as large as that of its muscle.

The articular cartilages in the human body consists of three components: the cells, the collagenous fibres, and the ground substance. The cells of hyaline cartilage usually are spherical, although there are many exceptions. Thus, in the layers of the cartilage under perichondrium and under the free joint surface the cells are flattened in a plane parallel with the surface. Caused by all side pressure they are hemi-spherical or angular in the lower layers. The cells are often connected in small or large compact groups, which we usually call chondrones. This groups may be rounded or stretched into small columns lying in one line. Inside the chondrones, it means between the separate cells, the interstitial substance is very rare or may even be absent. The collagenous fibres from cartilage seem to be much the same as those from connective tissue. The interstitial substance contents chondromucoid, a complex protein which yields chondroitic acid on hydrolysis.

Experimental investigations have shown, that the cells of connective tissue can be transformed into cartilage cells, if the connective tissue has been subjected to pressure during some time.

The architecture of the collagenous fibres in the articular cartilages is very complicated. In this figure a scheme has been drawn and

---

de trabajo y de responsa bilidad funcional, la lealtad más fervorosa hacia los más elevados ideales e intereses de la Patria.

La Dirección General de Educación Física de la Secretaría de Educación Pública, se propone llevar a cabo durante el año de 1957, consagrado a la Constitución Política de los Estados Unidos Mexicanos, el presente Plan de Trabajo.

you can see that the fibres coming from the basal part of the cartilage go up to the superficial part and after an arcade they return to the base. Round the cellgroups the fibres are arranged like a net around a ball. The chondromucoid has a gelatinous consistance. The arrangement of the cells, of the collagenous fibres and of the ground substance and their physical properties will give the cartilage a good elasticity and compression ratio.

If a joint is stimulated for a long time by hard training the cellular and intercellular parts of the cartilage react in the same way as they did in the connective tissue. First of all many new cells will appear and after that the intercellular substance will hypertrophy. This last mentioned process will reach much higher values than the new formation of cells. Thefore, the number of cells per unit of volume will successively decrease.

In order to demonstrate those processes I will show you some diagrams from a paper published by one of my co-workers. As experimental animals he used guinea-pigs. One group had no training and the other one was trained during 100 days. From the last group, animals were taken out for examination after 20, 40, 60 and 80 days. From this curve you can see that during the first three weeks the number of cells per unit of volume increases, and after that there was a successively decreasing during the rest of the training period, so that the last group exercised had a lower value than the controle material. There was a good parallelism between the number of cells per chondrone and unit of volume. This means that during the first period of training every chondrone will include more cells than before the training. Later on, on the other hand, this number of cells will decrease, depending on a more marked formation of intercellular substance, wereby the cells are removed from each other.

In the connective tissue we can see that the training has an influence on the smallest parts of the collagenous substance, that is on the fibrils. Here we can see the influence of the training upon the average volume of cells. This volume increases gradually during the training showing the fundamental importance of the function for the structure of every tissue.

The proportion between the cellular and the intercellular substance during the first part of the training was temporarily changed in favour of the cellular one. After that this proportion diminished.

Histologically you can always see three different layers in the uncalcified part of the articular cartilage, the tangential, the transitional, and the radial zone. The transitional zone is the most vital one and therefore it is best suited for studying the abovementioned problems. In the radial zone it is very likely that there is a reproduction of cells, though a relatively slight one. When this occured in the tangential zone, however, it appeared to be very limited. The cells in this zone seem to originate from those of the transitional zone through a secondary displacement.

Physically this will cause an increase of the compressibility of the articular cartilages. A high compressibility is from a functional point of view of great value, because it will give a good possibility of compensating the eventual incongruences of the articular surfaces of the cartilages, so that these surfaces will increase and the load per unit of square so decrease.

From a functional point of view this must be considered as suitable.

In order to illustrate this, I want to show you a picture with two different figures. The left one is a histological section from a joint of an untrained rabbit. The right one is a section from the corresponding joint of a rabbit of the same age, trained during three months. You can easily see the differences in the thickness of the cartilage, the magnitude of the cells, the number of cells in the different cellgroups, and the amount of intercellular substance.

Until now we have studied the changes in the articular cartilages caused by rather long training periods, about three months. Using special methods we have been able to prove the functional adaptability of articular cartilages for a short time of training too. We have studied the thickness variations of the articular cartilages of the knee joint using a special X-ray equipment.[5] As experimental animals we used rabbits. They were taken from their hutches in which they could run at will, and bound in the registration apparatus for a period of 60 minutes. They were radiographed immediately after being bound and after 30 respectively 60 minutes. With as short an interval as possible the animals were than released and trained during 10 minutes. They were then tied into the registration apparatus again as quickly as possible, and a radiograph was taken about 3 minutes after the terminated training, and after 30 respectively 60 minutes. The results obtained can be studied in this figure, from which it is apparent that during the first half hour's rest the cartilage diminishes in thickness. The decrease in the thickness of the cartilage on the tibial and fibular side of the knee joints is 7 respectively 11 per cent. During the second thirty minutes' rest there is only a slight decrease of the thickness. During the 10 minutes training 98 per cent of the animals show an increase in the total thickness of the cartilage. This increase is striking and amounts to about 13 per cent of the total thickness of the cartilage.

How pronounced this increase is can be seen from the following: the thickness of the cartilage after the animal has been allowed to run about at will in its hutch compared with the thickness shown immediately after 10 minutes training show a clear increase in 95 per cent of the cases.

During the first half hour's rest after the terminated training a decrease in the thickness of the cartilages will occur. This decrease is relatively large and it amounts to about 10 per cent of the total thickness. Also during the second half hour's rest after training there is a relative decrease in thickness which amounts to about 2 per cent.

As this increase in the thickness of the cartilage must be interpreted as a rapidly occuring increase of the cartilaginous substance, it must be presumed that this is due to a supply of fluid to the cartilage. Now the question arises, where this fluid comes from and through what passage it enters the cartilage. As the cartilage is devoided of blood vessels, there are but two ways in which the fluid might plausibly have entered, to wit, from the surface facing the articular space or via the most basal parts of the cartilage facing the bone.

Since long ago it is known that the joints are only slightly filled with joint fluid and that the articular surfaces are covered with a very thin fluid membrane. It therefore seems hardly credible that a pressing of the articular surfaces against one another can involve a pressing of the fluid into the cartilage. A suction of fluid from the articular space into the cartilage when the latter is unloaded might plausibly involve the observed increase in thickness. Some experimental observations have been done, however, in order to support the correctness of this assumption.

Our studies on rabbit and human joint have provided a new concept of the marginal zone between the cartilage and bone. In all joints contact exists between the articular cartilage and the marrow spaces. The calcified zone of cartilage is usually the one that is in contact with the marrow spaces, but in some cases projections from the bone marrow penetrate beyond the calcified zone into non-calcified cartilage. The size and frequency of such interconnections between cartilage and marrow spaces vary from joint to joint. The maximal area of contact between joint cartilage and marrow is about 8 per cent and the minimal area about 3 per cent.

In some of our investigations when using radioactive isotopes it has been proved that under normal intravital conditions the nutrition of the joint cartilages takes place partly from the synovial fluid and partly via the direct contacts between the epiphysial marrow spaces and the basal layers of the cartilage. The quantitative relation between these two nutritional means varies. During function it is probable that the inflow from the marrow spaces rises more than from the synovial fluid.

The just mentioned short time functional adaptability of the articular cartilages can be studied with a special form of histological technique. This technique gives a good view of the intravital conditions of the cells, which is not the matter with the ordinary histological methods. In this way we were able to see, that there are microscopical differences between cartilage from the trained and from the untrained knee-joint of the same animal. Those differences, however, were restricted to the upper layers of the cartilage. Cells so located in cartilage from exercised joints had not the flattened form usually exhibited by sections of tissue specimens that are studies with earlier techniques. The outermost cells had assumed an ellipsoid shape and those in the next layer were more rounded, sometimes true spheres, as you can see on this picture.

Furthermore, the cells in the outermost layers from the resting joint were not quite so flat as the corresponding cells in cartilage specimens that were subjected to standard histological procedures. Anyhow the differences between exercised and resting articular cartilages were clear and could be demonstrated after as little as 15 minutes of exercise. This is demonstrated in the next figure.

From a physical point of view this form of functional adaptability will give the same qualities of the articular cartilages as the training during a long time, that is, it will give an increase of the compressibility which, as has been stated above, must be suitable for the function of the joint. For the gymnastic training this type of adaptability of the joints is of great importance.

It is of importance to point out that what I now have said about the functional adaptability of the articular cartilages is only representative for those parts of the surface which normally are loaded. The other parts have not this good adaptability, and I think that their nutrition is rather bad. These facts are to be remembered in gymnastic trainings, and therefore, I mean, we have to avoid extreme movements and loading of joints in such positions. We also have to remember that an injury of an articular cartilage cannot be healed with the same substance but only with connective tissue. Such an injury will always give a scar which has other physical qualities than the cartilage.

In connection with these problems I think we have to discuss the abrasion of the articular cartilages and the synovial fluid during exercise and rest. Since more than 60 years it has been stated that normal function of healthy joints has an abrasive effect on the surface of the articular cartilage and of the synovial membrane, that is the inner layer of the joint capsule. Under adequate magnification we can always see that the surface of a normal articular cartilage is not smooth and even. It is rough, because the outermost cartilaginous layers has been scratched. In the synovial fluid we can always see particles abraded from the cartilages and the joint capsule.

The quantitaty of the synovial fluid in the joints has earlier not been systematically studied. At our institute, however, we have done some investigations about this problem and here I want to give you a short summary of the results.

The volume of the synovial fluid varies strongly from animal to animal. The mean numerical value from all exercised knee joints was 0.079 cc. The corresponding values from the not exercised joints was 0.029 cc. When two joints from the same animal of which the right one had been exercised and the left one rested were compared, however, it turned out that the exercised joint always contained a larger volume of synovial fluid than the rested one. This can well be seen from this diagram. The proportion between the amount of synovial fluid in knee joints which had been exercised for half an hour until three hours and that in unexercised knee joints was 2.4 to 1. The magnitude of this quotient is related to the duration of the exercise: the longer the exercise, the higher will be the quotient.

The number of cells per unit volume of synovial fluid was higher in synovia from the resting joint than from the exercised joint of the same animal. 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.

The number of abraded particles per unit volume of synovial fluid varied greatly from joint to joint. Calculated in all the extracted synovia, however, the number of particles for the exercised joints exceeded that for the unexercised joint of the same animal. The increase in the number of particles was dependent on the type as well as on the duration of the function. The higher the joint was loaded the richer was the found particles. Also when the duration of the exercise was prolonged the same tendency was manifest. This particles origin from the articular surface of the cartilage. It means that we always have a loss of articular cartilage tissue during exercise of a joint. This loss is compensated through a new formation of tissue probably from the transitional zone of the cartilage.

Also the bone has a good functional adaptability. It consists of cells, masked collagenous fibres, similar to those of the connective tissue, and a hard interstitial substance. This substance consists of carbonates and phosphates of calcium, and attains a maximum of approximately 65 per cent of the dry, fat-free weight in adult life. In the bone under development and after a long time of inactivity this proportion can be as low as about 40 per cent. If such a bone is exercised and loaded for a time the lastmentioned proportion will increase, and will after a relatively short time be the same as before the period of rest. We do not know the details of the atrophy of the organic part of the bone during inactivity. The cells and the collagenous fibres, however, are principally the same as in connective tissue. Therefore they probably react in the same way as has above been described for the tendons, the ligaments and the cartilages. This adaptability is possible because the metabolism of the bone is much higher than earlier has been thought. Not only the quality and the new formation of this tissue but the growth of the bones also is stimulated by exercises.

From what is stated above it is clear that all the different tissues of the static part of the locomotion organs have a functional adaptability of greatest importance for its function. Therefore the conclusion can be drawn that gymnastic exercises are of great value in all ages.

The muscular tissue has two distinct types: smooth muscle and striated muscle. As a rule, smooth muscles contract independently of voluntary controle while the striated muscles are subjected to voluntary control. Cardiac muscle, although striated, is involuntary and contracts automatically and rhythmically. Smooth muscle shows a very closed relationship to the ordinary connective tissue. It forms the contractile portion of the wall of the digestive tract, the duct of the glands, the respiratory passages and the urinary and genital ducts. The walls of the blood-vessels also consist to a considerable extent of smooth muscles. This part of the muscular tissue is therefore only of small importance when we are speaking about the morpho-physiological aspects of gymnastic exercises. In spite of this we always have to remember that this tissue is of great importance for the nutrition of most of our organs and that the smooth muscle has the same functional adaptability as mentioned above for the static parts of the locomotion organs.

The striated muscular tissue consists of long cylindrical muscle fibres, with a thickness fluctuating from 10 to more that 100 μ. In a non-tapering muscle the fibres apparently continue without interruption through the entire muscle so that their length is equal to that of the muscle.

A muscle is formed of parallel fibres, held together by connective tissue. The muscle fibres combined to form the primary bundles; severel primary bundles combined to form secondary bundles; tertiary bundles are formed by secondary ones, etc. Large bundles and layers of interstitial connective tissue at the periphery of the muscles project into the spaces between the bundles of muscular fibres. These thick layers branch and send thin layers between the smaller bundles. Where a muscle is attached to a tendon there is a very close union of the muscle fibres with the collagenous bundles of the tendon.

During intensive activity the skeleton muscle increase in volume. This depends on the enlargement of the already existing fibres. During inactivity the process in inverse.

Evererybody who is orientated about the problems of gymnastic exercise knows that the muscular force decreases in higher ages.

If we are studying the volume of the muscles of the locomotion organs we find, that the muscles does not diminish between 20 and 55 years of age. This is illustrated in the next figure where the width of the roentgenographical muscle shadow in healthy persons can be seen. Neither histological nor chemical registrations have shown any degenerative processes of the muscle fibres in this period. The diminishing of the muscular force just mentioned therefore was unexplained until we some years ago studied the human striated muscular tissue with morphologic, chemical and roentgenographic methods.

The adopted morphologic technique very seldom revealed intramuscular fat in newborns. It was occasionally seen in the form of globules around the large intramuscular vessels. Perivascular fat became more abundant with increasing age; simultaneously fat begins to occur in the intramuscular connective tissue spaces. After age 30—40 fat also entered the small tissue spaces, perimysium internum, thereby to some extent separating the muscular fasciculi.

By comparing biceps brachii and gastrocnemius sections from the same corpse it was found that a muscle of the arm always contains less fat than the leg muscle. These variations were particularly noticeable after about age 30, owing to the age variations of fat.

There was one other size of intramuscular fat, just beneath the muscle-fascia. Our term for it is subfascial fat. Apparently such fat also, judging by the corpse specimens, increased in frequency and amount with increasing age. In young persons with no subfascial fat the fasciculi lay immediately underneath the muscle fascia. When subfascial fat was present, however, it appeared as though a membranous layer of adipose tissue were interposed between the fasciculi and the muscle-fascia, separating the two.

The chemical results can be summed up in the following way. At birth the fat content of the muscles is about 7 per cent. It then increases gradually in the gastrocnemius so that about 30 per cent of the muscular dry substance is composed of fat at the age of 75 years. The biceps brachii has no corresponding increase but such a one might be seen after 60 years of age.

Using a special roentgenographic method the intramuscular and subfascial fat can be studied very well. The technical details of this method are complicated and too timeconsuming to mentioned here.

When studying healthy subjects of different ages we got the following results. As you can see in this figure, the interstitial fat was visualized roentgenographically the more often, the higher the age of the person was. Roentgenographic visualization of interstitial fat was extremely rare in the age-group 20—25 years. Thereafter the increase was more or less rectilinear until age 50—55.

The mean frequency of interstitial fat was greater in women than in men, but the difference was not significant in any of the separate age groups. Another roentgenographic result was, that the leg muscles contained interstitial fat more often than the thigh muscles. The correlation between roentgenographically visible interstitial fat in the thigh and leg muscle was strongly positive. It is of interest to see that there is no correlation between subcutaneous fat and the presence of interstitial fat.

The frequency of roentgenographically visualized subfascial fat is illustrated in this figure. Subfascial fat was evidently seen oftener the older the roentgenographed person was. After age 50—55 the frequency of subfascial fat seemed to remain in fairly constant. The curves for women lay on a higher level all along than those for men. It is also of importance to note that there is a strong positive correlation between the frequencies of the interstitial and subfascial fat, but no correlation between the thickness of interstitial fat and the width of roentgenographic muscular shadow.

The breadth of a roentgenographic shadow of a muscle is proportional to its volume. The latter is not influenced by increasing age. Since, however, it has been shown that the amount of interstitial fat increases with age, the constant muscular volume indicates that in time the amount of true muscular tissue in a muscle diminishes and is largely replaced by adipose tissue. This phenomenon explains the dimishing of the muscular force in higher ages, a fact, which always must be remembered in gymnastic exercises.

In this lecture I have given a short review about some morpho-physiological problems of gymnastic exercises. Here nothing has been said about the nervous system because doctor Andersen gave a lecture about morpho-physiological problems yesterday, and I have not discussed the heart, the vessels and the lungs because their morpho-physiological problems are often discussed and described.

My intention has been to give a short review of scientific problems which might be of interest in practical work with gymnastic exercises.

Aspects Morpho-Physiologiques des Exercices de Gymnastique

Par le Professeur Bo E. Ingelmark
de l'Université (Institut Anatomique)
de Gothembourg (Suède)

Résumé

L'auteur donne une revue sommaire du pouvoir d'adaptation des tissus conjonctifs, des cartilages, des muscles et du système nerveux. Chaque forme de bonne gymnastique suscitera une hypertrophie harmonieuse des

organes statiques et dynamiques du corps humain en son entier.

Dans le tissu conjonctif, l'entraînement occasionnera tout d'abord un accroissement du nombre de cellules; puis, dans la substance intercellulaire se révélera une hypertrophie telle que le nombre de cellules par unité de volume amoindrira. Une tension fonctionnelle accrue cause une hypertrophie relativement égale des tendons et du système musculaire correspondant. Ce procès peut être observée dans les tendons, dans la partie extérieure des capsules synoviales et dans les ligaments; ce qui accroît la résistance de ces tissus aux déchirures.

L'atrophie des cartilages articulaires dans une articulation après une période de repos plus ou moins longue, est connue. Par contre, l'hypertrophie de ces cartilages semble être incertaine, étant donné qu'ils n'ont pas de véritables vaisseaux sanguins. Il faut donc que l'alimentation soit bien faible; c'est ce qui a été prouvé aussi par des essais ultérieurs. Ces dernières années, quelques savants suédois (Ekholm, Holmdahl, Ingelmark et Sääf) ont été en mesure de prouver que les cartilages articulaires, tant chez des animaux d'expérience en croissance que chez des animaux adultes (lapins et marmottes) croissent.

Une ou deux semaines après que l'entraînement a commencé, le nombre relatif et la grandeur des cellules accroît. Ensuite, l'humeur intercellulaire commence par augmenter plus vite que la substance cellulaire et après quelques mois les cartilages articulaires contiennent plus d'humeur intercellulaire, en comparaison avec l'époque avant l'entraînement. L'on peut admettre à juste titre que ce procès aura comme conséquence un ramolissement des cartilages. L'inégalité des surfaces articulaires et des cavités articulaires en peut être compensée facilmente. Ce qui signifie que la tension sera répartie sur une surface relativement grande, de sorte que la tension par unité de surface de contact se maintient à un chiffre assez bas, même dans le cas où l'articulation doive supporter une grande charge. Or, cette adaption fonctionnelle pourrait être considérée comme parfaitement convenable à la fonction des articulations. Des essais identiques à ceux dont est question ci-dessus, faits sur des animaux d'expérience, n'ont pas encore été faits sur l'homme. Or, les cartilages articulaires de l'homme ressemblent beaucoup à ceux d'autres mammifères, tant en ce qui regarde leur structure qu'en ce qui regarde leurs propriétés naturelles et métaboliques. Il s'ensuit donc qu'il y a concordance entre l'adaptation fonctionnelle des cartilages articulaires de l'homme et ceux des animaux d'expérience susmentionnés.

Il a été prouvé que les cartilages articulaires des animaux d'expérience et de l'homme révèlent encore une autre adaptation fonctionnelle, qui apparaît aussitôt. Un entraînement de quelques minutes seulement d'une articulation qui s'est tout d'abord reposée, donne un accroissement de l'épaisseur du cartilage articulaire. Après un repos d'une demi-heure jusqu'à une heure, les cartilages articulaires reprennent leur épaisseur d'auparavant. Or, il va de soi que ce subit accroissement (suivi d'un subit amoindrissement) ne saurait être causé par la production du tissu. La seule explication acceptable de ces modifications dans le cartilage s'entend, respectivement: une absorption et un écoulement de l'humeur. C'est ce qui a été prouvé au moyen d'une méthode tout spéciale permettant d'observer des particules microscopiques du cartilage d'articulations en repos et du cartilage d'articulations qui viennent d'être entraînées. Ainsi, dans ces derniers cartilages, les cellules sont beaucoup plus grandes que dans le cartilage cité en premier lieu. Il y a deux façons pour l'humeur d'entrer dans les cartilages: ou bien via des capsules synoviales dans la cavité articulaire, ou bien via les parties inférieures du cartilage vis-à-vis des os. La couche osseuse sur laquelle repose le cartilage est perforée et par ces ouvertures le tissu de la cavité moelleuse passe dans les parties inférieures du cartilage articúlaire. Les isotopes radio-actifs et la technique radiographique ont prouvé qu'une partie importante de l'écoulement de l'humeur vers les cartilages articulaires a lieu de cette façon. A la suite de ces observations, l'on acquiert une bonne connaissance de la façon dont a lieu la subite modification, que nous venons de décrire ci-dessus, de l'épaisseur des cartilages articulaires. Ceci réalisera, de la même façon comme celle décrite ci-dessus, un bon état fonctionnel pour les articulations.

Il est clair de ce qui précède qu'après un entraînement normal les cartilages articulaires accusent deux formes d'adaptation. L'une qui débute graduellement et qui exige plusieurs semaines avant qu'elle puisse être déterminée, constitute sans doute la production d'un nouveau tissu; alors que l'autre qui se révèle subitement dans quelques minutes, mais qui disparaît après une heure est causée par un écoulement d'humeur vers le cartilage. Mais ces deux formes d'adaptation signifient une modification matérielle des cartilages articulaires, de sorte que ces derniers seront mieux en mesure de porter les charges auxquelles ils seront soumis dans leurs fonctions d'ensemble.

Les os aussi possèdent une parfaite propriété d'adaptation fonctionnelle. Ceci s'applique tant aux parties organiques qu'aux partie inorganiques de ces tissues. Il a été possible de déterminer que les mêmes principes s'appliquent tant à l'hypertrophie de la partie organique des os qu'aux tissus conjonctifs.

La partie inorganique peut même dévier dans une mesure importante étant donné le degré métabolique élevé qui s'est révélé être plus élevé que l'on ne supposait tout d'abord.

La partie anatomique de l'adaptation fonctionnelle des muscles est connue depuis longtemps. Cela étant, l'auteur ne répète que succintement les principes correspondants. Un facteur très important est celui que des muscles se trouvant en bonne condition, révèlent toujours une meilleure coordination que des muscles atrophiés.

Cette meilleure condition ne doit pas être considérées comme une propriété du tissu musculaire, mais surtout comme une condition améliorée des centres corticaux et subcorticaux de la partie motrice du système nerveux central.

Enfin, l'auteur souligne quelques parallèles entre les adaptations fonctionnelles des organes moteurs et les systèmes vasculaires et respiratoires.

Aspectos Morfo-Fisiologicos de los Ejercicos de Gimnasia

Por el Profesor Bo E. Ingelmark
de la Universidad (Instituto Anatómico)
de Goteborg (Suecia)

Resumen

El autor nos dá una somera impresión sobre el poder de adaptación de los tajidos conjuntivos, de los cartílagos, de los músculos y del sistema nervioso. Toda buena forma de gimnasia, suscitará una hipertrofia harmoniosa en los órganos estáticos y dinámicos del cuerpo humano por entero.

En el tejido conjuntivo, el entrenamiento, ocasionará primero un acrecentamiento en el número de células; luego, en la sustancia intracelular aparecerá una hipertrofia tal que el número de células por unidad de volumen, disminuirá. Una tensión funcional aumentada, causa una hipertrofia relativamente igual en los tendones y en el sistema muscular correspondiente. Este proceso, puede ser observado en los tendones, en la parte exterior de las cápsulas sinoviales y en los ligamentos; lo que aumenta la resistencia de esos tejidos a los desgarros.

La atrofia de los cartílagos articulares despues de un período más o menos largo del reposo de la articulación, es conocida. Sin embargo, la hipertrofia de esos cartílagos parace póco probable, ya que carecen de verdaderos vasos sanguíneos. Su alimentación, por lo tanto, ha de ser muy débil, como se ha probado mediantes pruebas ulteriores. Estos últimos años, algunos sabios suecos (Ekholm, Holmdahl, Ingelmark y Sääf) han estado en condiciones de poder probar que los cartílagos articulares, tanto en los animales experimentales en la época de crecimiento, como en animales adultos (conejos y marmotas) crecen.

Una o dos semanas despues de empezado el entrenamiento, el número relativo y el tamaño de las células, aumentan. Luego, el humor intercelular empieza a aumentar más deprisa que la substancia celular, y en unos meses los cartílagos articulares contienen, en comparación con la época anterior al entrenamiento, mayor cantidad de humor intercelular. Puede admitirse, por consiguiente, que éste proceso tendrá como consecuencia un ablandamiento de los cartílagos. La desigualdad de las superficies articulares y de las cavidades articulares se compensarán facilmente. Esto significa que la tensión se repartirá sobre una superficie relativamente grande, de manera que la tensión por unidad de superficie de contacto, se mantiene en un número bastante bajo, aún en el caso en que la articulación debe soportar una gran carga. Por lo tanto, esta adaptación funcional podría ser considerada como perfectamente conveniente para la función de las articulaciones. Identicas pruebas como las hasta aquí reseñadas, hechas sobre animales experimentales, no han sido todavía hechas en el hombre. Sin embargo, los cartílagos articulares del hombre se asemajan mucho a los de otros mamíferos, tanto en lo que se refiere a su estructura como a lo que se relaciona con su propiedades naturales y metabólicas. Se deduce, pues, que existe una concordancia entre la adaptación funcional de los cartílagos articulares del hombre y los de los animales experimentales arribas mencionados.

Se ha probado además que los cartílagos articulares de los animales experimentales y del hombre son suceptibles aún de otra adaptación funcional que citamos enseguida. El entrenamiento de unos minutos solamente de una articulación que primeramente se ha mantenido en reposo, dá un aumento del espesor del cartílago articular. Despues del descanso de media hora o una hora, los cartílagos articulares han recobrado su anterior espesor. Por lo tanto cae de su peso que éste súbito aumento (seguido de un súbito aminoramiento) no está causado por el crecimiento del tejido. La única explicación aceptable de estas modificaciones en los cartílagos puede ser: una absorción y un desagüe del humor. Esto fué demostrado con la ayuda de un método especialísimo que permitió observar partículas microscópicas del cartílago de articulación en reposo y del cartílago de articulación que acaba de ser sometido a entrenamiento. En estos últimos cartílagos, las células son mucho más grandes que en el cartílago citado en primer lugar. Existen dos maneras de que el humor entre en los cartílagos: o bien por vía de las cápsulas sinoviales en la cavidad articular, o bien por les partes inferiores del cartílago frente al hueso. La capa ósea sobre la cual reposa el cartílago está perforada y por esas aberturas el tejido de la cavidad medular pasa a las partes inferiores del cartílago articular. Los isótopos radio activos y la técnica radiográfica han probado que una parte considerable del paso del humor hacia los cartílagos articulares se produce de esta manera. Consecuentemente a estas observaciones, se adquiere un sólido conocimiento de la manera de verificerse la súbita modi-

ficación que acabamos de describir más arriba del espesor de los cartílagos articulares.

De lo anteriormente dicno, se desprende claramente que despues de un entrenamiento normal, los cartílagos articulares acusan dos formas de adaptación. Una que dá comienzo gradualmente y que necesita varias semanas antes de que pueda ser determinada, constituirá, indudablemente la producción de un nuevo tejido; mientras que la otra que aparece subitamente en algunos minutos, pero que desaparece también al cabo de una hora, la produce un desagüe de humor hacia el cartílago. Pero estas dos formas de adaptación significan una modificación material de los cartílagos articulares, de modo que estos últimos se encuentren en mejor forma de poder soportar las cargas a las cuales se vean sometidos en su función de conjunto.

También los huesos poseen una propiedad de adaptación funcional perfecto. Esto es aplicable tanto a la parte orgánica como a la inórganica de estos tejidos. Se ha podido probar que los mismos principios pueden aplicarse tanto a la hipertrofia de la parte orgánica de los huesos como al tejido conjuntivo.

Le parte inorgánica, llega a evolucionar de manera hasta importante, debido al elevado grado metabólico que según se ha sabido es más elevado de lo que en un principío se creía.

La parte anatómica de la adaptación funcional de los músculos, es conocida desde hace tiempo. En consecuencia, el autor, se limita a repetir sucintamente los principios correspondientes. Un factor muy importante es el de que los músculos que de encuentren en buenas condiciones, realizan siempre una coordinación mejor que los músculos atrofiados.

Esta mejor condición, no debe ser considerada como una propiedad del tejido muscular, sino sobre todo como un mejoramiento de los centros corticales de la parte motriz del sistema nervioso central.

En fin el autor subreya algunos paralelismos entre las adaptaciones funcionales de los órganos motores y los sistemas vasculares y respiratorios.

Observations on Experimental Muscular Soreness

From the Laboratory for Theory of Gymnastics, University of Copenhagen
(Acta Rheum. Scand. 2/1956)

by Erling Asmussen

Muscular soreness following hard and unaccustomed exercise is a phenomenon well known to athletes, gymnasts, soldiers, amateur workmen, etc. as well as to physicians and physio-therapists who are consulted by them. It generally makes itself conspicuous locally in muscles that have been exerted vigorously, mostly on the day after the exercise. The soreness is often accompanied by a certain stiffness and swelling that can be felt objectively and in grave cases may even be seen. It often increases for a day or two and then gradually diminishes to disappear after about 7 days.

Muscular soreness has been described and its appearance studied by Hough (1902) in ergographic investigations. Hough found that this kind of soreness did not vary with the intensity of fatigue but that it was closely associated with mechanical tensions in the muscles. He suggested that some sort of rupture within the muscle itself be the cause of the phenomenon and pointed especially to the connective tissue as the site for these ruptures. Hill (1951), in reviewing the mechanics of voluntary muscle, mentions the stiffness and pains which follow hard and unaccustomed exercise as one well-known fact of which no convincing explanation can be given. He dismisses the assumption that lactic acid and undue acidity should be the cause of lack of evidence and seems inclined to believe, as did Hough, that the soreness is due to mechanical injury, distributed microscopically throughout the muscle.

In the Scandinavian medical literature, Helweg (1934) has given a description of a common condition — which he termed "*myopathia e functione*" — which in all details seems to cover the kind of muscular soreness so well known to athletes. As the probable cause of the pains Helweg, in accordance with the dominating ideas on muscular contraction of those days, suggested local accumulation of lactic acid or other waste products from the anaerobic muscle metabolism. The swelling that accompanied the soreness was thought to be due to physico-chemical changes of the muscle fibers themselves, but later attempts to find histological evidence for this have failed. It may further be noticed, that Buchthal & Clemmesen (1940) found that the palpable changes were not due to maintained weak contractions, as electromyographically these parts of the muscles behaved as normal resting muscles.

Bøje (1955), from clinical experience, is inclined to believe that the pains are located in the intramuscular connective tissues, as they are most apt to develop after exercise that have extended the muscles.

Often this kind of late muscular soreness is not distinguished from the ischemic pains that develop during hard muscular exercise with more or less anaerobic conditions in the muscles. It is, therefore, often presumed that muscular soreness or stiffness as here described is also caused by metabolic waste products.

As will appear from the above, two possible explanations of the muscular soreness have been suggested: 1) It may be due to the highly intensified and dominantly anaerobic local metabolism that accompanies exercise, or 2) it may be due to the mechanical stress that the muscle fibers and/or connective tissue undergoes during development of tension.

In order to test which of these explanations that best fits the known facts, experiments with hard positive and negative work were performed. In positive work (e. g. lifting a weight) the muscles shorten during contraction, overcoming external forces (as for instance gravitation). In negative work (e. g. lowering the same weight) the muscles are lengthened by external forces, braking the movement. If the speed of movement is steady the tension developed by the muscles will be the same for all identical positions in the two kinds of work. Experience, checked by experimental evidence, shows, however, that negative work costs much less in metabolic expense than does the same amount of positive work (e. g. Asmussen 1952, Abbot, Bigland and Ritchie 1952). The muscle-physiological explanation of this fact is given in the two papers just mentioned and in the paper by Buchthal, Kaiser and Rosenfalck (1952).

The experiments were performed in the way that a muscle group in one extremity performed positive work while the same muscle group in the other extremity performed the same amount of negative work. If metabolic waste products were responsible for the muscular soreness the "positive" extremity should be expected to be the site for the soreness, but if the mechanical tension set up in the muscles was the direct cause of the soreness it was to be expected that both extremities would suffer to about the same degree.

Procedure

Two sets of muscles were tested, viz. the extensors of hip and knee (henceforth referred to as the "quadriceps") and the extensors of the elbow (called the "triceps"). The former muscles were exercised by having the subjects step up on a 50 cm. high stool using the same leg for the ascent throughout the whole experiment, and immediately afterwards descent again this time using the other leg to do the negative work. The movements were slow and it was attempted to keep the same speed of movement in both ascent and descent. The second muscle group, the triceps, did positive work by lifting a weight of 5 to 7 kg. suspended in a string over a pulley by an extension of one maximally flexed elbow. Now the other arm took over through another string and slowly lowered the weight by a braked flexion of the elbow. For these experiments the subjects were sitting in an arm chair, their backs against the pulley, and resting their horizontal and parallel upper arms and elbows on a padded piece of board lying across the arms of their chair. Work was continued till fatigue set in. *This always happened first in the muscles that did positive work.* After a pause of a few minutes for recovery, work was taken up again and continued till fatigue or exhaustion made a new rest necessary, and so on for 3 to 4 bouts of work. The following day the subjects were examined by palpation and interview by a trained physio-therapist, and again on the second day after exercise. Soreness and palpable changes were listed, if present, in three arbitrary degrees. 16 female students from Teilmann's Institute for Physio-therapy served as subjects. Previous examination had shown them to be free of muscular soreness or palpable muscular anomalities.

Results and discussion

The results are presented in Table I. It is obvious that soreness and palpable changes are much less common in the muscles that had been doing positive work than in the "negative" muscles although fatigue or even exhaustion had been the rule in the former group but hardly ever in the second group of muscles. The subjective and objective changes were in many cases more pronounced on the second day after the exercise, and the muscular soreness and stiffness in the quadriceps was sometimes so severe as to prohibit normal standing and walking. As mostly found, the anomalities were especially conspicuous at the attachments to tendon and fascia, e. g. along the tractus ilio-tibialis.

These experimental results make it very unlikely that excessive production of metabolic substances should be the cause of this late form of muscular soreness. The metabolism probably has been 5 to 7 times more intense in the muscles doing positive work, and as fatigue developed some ischemic pain often was felt here. But this pain disappeared soon after cessation of work and did not reappear. The negatively working muscles on the other hand gave no sensations of pain during or immediately after the work period, but 12 to 36 hours later they were the site of marked muscular soreness.

If intensive metabolism is not the cause of the muscular soreness, it is reasonable to assume that it is mechanical tensions developed in the muscles that cause the changes leading to soreness. As mentioned earlier, the tensions in the positively and negatively working muscles must have been approximately equal. It may seem strange, then, that the soreness was so much more pronounced in the negatively working muscles. The explanation of this finding may be that whereas every single active muscle fiber during shortening looses tension, the single muscle

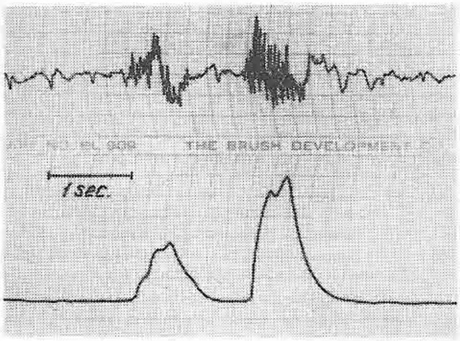

Fig. 1. Upper recordings: Electromyograms from quadriceps muscle during free standing knee-flexion and -extension. Below: Simultaneously recorded integrations of the electromyograms. Small plate electrodes.

fibers during forced lengthening gain in tension (e. g. Buchthal et al. 1951). As a result, in order to produce the same amount of total muscular tension during *shortening*, the number of active motor units must be increasing, whereas during *lengthening* it must be decreasing. In other words, in positive work the necessary tension is produced by a greater number of muscle fibers than in negative work, as also evidenced by electromyography (Fig. 1). The tension per active unit will consequently be greater in negative work than in positive, and so the changes of strain or damage to parts of the muscle.

The site of the injury by the high tensions during exercise cannot be stated with certainty. But the fact that the pains are mostly localized to those parts of the muscle where connective tissue is most abundant, viz. tendinous attachments, together with the fact, that the muscle fibers themselves are highly elastic as compared to the rather stiff intramuscular connective tissue, points to this latter as the site of the injury. This injury need not necessarily be actual ruptures, for these would probably have happened during actual work and so would most likely have given rise to immediate sensations. Rather one might imagine, that the high tension has initiated a slow reaction in the connective tissue, causing the development of the actual pain-producing condition. It is tentatively suggested that the soreness is caused by a swelling of or in the connective tissue, causing it to be distended at right angles to its natural direction of traction. It is well known that intramuscular hematomas, or infusions of fluid will cause pains by distending the tissue. An increased formation of extracellular fluid in the connective tissues may secondarily influence the blood flow by blocking capillaries and thus augment the edema and the muscular soreness. The close relation between muscular swelling and soreness would thereby be explained.

My thanks are due to Mrs. M. Hoeck who performed the physio-therapeutic examinations of the subjects, with a few exceptions which were done by Mrs. Ruth Christensen and Mrs. Doris Johnsen. The cooperation of sixteen students from Teilmann's Institute as subjects is also gratefully acknowledged.

Summary

In order to find out whether the muscular soreness which appears 12—24 hours after a bout of hard unaccustomed exercise, is due to the greatly increased metabolism in the working muscles, or whether it is caused by injuries evoked by the mechanical tensions in the muscles, a series of experiments were performed with positive and negative work. The tensions developed during these two kinds of work were the same in both cases, but the metabolism is known to be several times greater with positive work than with negative work.

It was found that muscular soreness with palpable muscular changes was always present 1 to 2 days after negative work, but hardly ever after positive work of the same intensity.

It is concluded that muscular soreness is called forth by mechanical stress most probably to the intramuscular connective tissue, and not by metabolic waste products. The reason for its apperance in negative work and absence in positive work is discussed, and a tentative proposal for its causes is given.

Résumé

L'auteur a fait une série d'expériences comportant des travaux positifs (soulever un poids ou monter sur une chaise) et négatifs (abaisser un poids ou descendre d'une chaise) pour vérifier si la douleur musculaire apparaissant 12—24 heures après un travail dur et inaccoutumé est due à un accroissement de métabolisme dans les muscles en action ou bien si elle est provoquée par des lésions évoquées par les tensions mécaniques dans les muscles en question. Les tensions développées pendant ces deux types de travail étaient les mêmes dans les deux cas mais on sait que le métabolisme est plusieurs fois plus grand dans un travail positif que dans un travail négatif.

Il fut constaté que la douleur musculaire comprenant des altérations musculaires palpables se présentait sans exception 1 ou 2 jours après un travail négatif, mais presque jamais après un travail positif de même intensité.

L'auteur en conclut que la douleur musculaire est provoquée par la tension mécanique exercée le plus probablement sur le tissu conjonctif intra-musculaire et non pas par les résidus métaboliques. Il discute ensuite la raison de sa présence après un travail négatif et de son absence après un travail positif, et soumet une proposition tendant à en expliquer les causes.