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Ergonomic Assessment of Physical Health Status of Workers Involved in Construction

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I. INTRODUCTION

The construction industry in India is an integral part of the nation and can be identified as one of the rapidly growing sector which gives employment to maximum of the workers after agriculture. Construction workers are the backbone of the Indian economy as they create the infrastructure necessary for industrial growth. Construction work provides employment and growth of other parallel industries such as cement, paint, wood, electrical work, hardware etc. It is basically a labour intensive industry which provides livelihood to many people in India. Increasing number of population living in urban areas and towns have taken up construction work as a means of immediate employment beside rural population as it assures for at least day to day sustenance of their family life.

The workers who work in construction industry perform a large variety of duties like building, repairing, mixing sand, cement, concrete, spreading concrete & other materials etc. The work place, work and environment lead to many problems as the construction workers are exposed to a wide variety of health hazards at work. The work involves hard physical labour under difficult conditions including hot, cold and wet weather. Construction activities performed by the workers are usually repetitive and involve a variety of postures bringing body discomfort to the workers. The importance of correct work posture is directly related with efficiency, comfort and good health.

Postural discomfort and musculoskeletal pain felt by individuals is directly associated with the feeling of how hard or light the work is. The workers perception of exertion during physical work denotes the strain on human body. Perceived physical exertion seems to reflect the balance between physical work demands and physical capacity of the individual.

The need for industrial ergonomics is on the rise today, because organizations are experiencing increased costs without it. Compatibility between the construction workers, work and work environment can be brought about by the use of Ergonomics the goal which is to find a 'best fit' between the worker and job conditions. Ergonomics tries to come up with solutions to make sure that workers stay safe, comfortable and productive. The strategies usually involve changing tools, equipment, materials, work methods or the workplace itself.

There are many laws and regulations applicable for the construction industry but their implementation has been notably poor. There is also high incidence of child labor in this industry. Attention to their working conditions and welfare is of recent origin. After several attempts the Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act 1996 was passed in India which provides for the establishment of construction workers' welfare board on a tri-partite basis. However, the position of the construction workers continues to be unsatisfactory and much needs to be done beginning from mapping the profile through the primary data on different aspects of construction labour to specific measures for the benefit of this labour.

Although many modern management health and safety professionals have now realized the importance of ergonomics in construction industry and few are making efforts to achieve the desired goals, a concerted effort should be made for the welfare of the labour force in the country. To obtain firsthand information on occupational health and safety problems and to find appropriate measures through ergonomics approach for the ill effects of bad work postures and musculoskeletal problems much needs to be done in the area of construction industry workers especially in the Indian context.

Thus, the initiative through present research is intended to analyze postural musculoskeletal problems and the risks associated with job task along with the exertion perceived while performing construction work manually by the workers. The suggestive ergonomic measures will benefit health and

safety professionals, tool designers and especially the construction workers themselves to increase productivity and efficiency. This will also help to reduce the exertion confronted by them in house construction occupation. Safety consciousness among construction workers through training and education can be percolated at the actual construction sites through such studies.

Objectives Of The Study

The present study on wasplanned with the following objectives :-

- ❖ To study the background and work profile of the construction workers.
- ❖ To analyze the physical health status of the construction workers in manually performed construction activities.
- ❖ To study the postures used by the construction workers.
- ❖ To assess the exertion perceived by the respondents while undertaking manual construction work.

Delimitations

1. The study was delimited to workers involved in house building construction**.**
2. The study was delimited to Udaipur city.

Definitions

A "skilled worker" is one who is capable of working independently and efficiently and is specialized for particular job in construction industry.

An "unskilled worker" is one who possesses no special training or previous experience, but is familiar with the occupational environment.

II. METHODOLOGY

Descriptive cum exploratory research design was used to analyze background and work profile, physical health, postures and exertion perceived by the respondents. The study design was as follows :

1. Sample selection: The present study was conducted in Udaipur city (Rajasthan). Purposive sampling was done and thirty skilled and thirty unskilled male respondents who were engaged in the house construction work for at least one year were selected as sample.

2. Development of tool: Aquestionnaire was developed to find the personal characteristics and work profile of the respondents. It also elicited information regarding construction activities performed by the respondents, frequency of performing these operations and time spent per day during work. The postures used during work were photographed and analyzed.

Determination of physical health in general terms was done using :

a) Body Mass Index (BMI) : Body Mass Index is a simple index of weight-for-height that is commonly used to classify underweight, overweight and obesity in adults. The formula used for calculation is–**BMI (kg/m^2) = Weight (kg)/ Height (m^2).** The data procured was analyzed according to the following BMI classification given by Garrow (1984).

BMI Class	Presumptive diagnosis of BMI	Body Type
<16.0	CED Grade III (severe)	Ectomorph
16.0-17.0	CED Grade II (moderate)	
17.0 -18.5	CED Grade I (mild)	
18.5-20.0	Low weight normal.	
20.0-25.0	Normal	Mesomorph
25.0-30.0	Obese grade I	Endomorph
>30.0	Obese grade II	

*CED-Chronic Energy Deficient

Body type of the respondents was determined on the basis of BMI scores :Ectomorph (BMI <20), Mesomorph (BMI between 20-25) and Endomorph (BMI >25). High values of BMI indicate excessive fat stores, while low values indicate reduced fat stores. This usually indicates the diet of a person which in turn affects the health.

b) Aerobic Fitness: It serves as measure of stamina and all round physical condition of the individual. It is measured in terms of VO_2 max(l/min) i.e. the ability of heart and lungs of the person to supply oxygen to the body. Respondents' aerobic capacity was determined by the equation derived by Varghese et.al. (1994).

VO_2 max (l/min) = 0.023 x Body weight (kg) -0.034 x Age (yrs.) + 1.652

VO_2 max (ml/min) = VO_2 max (l/min) x 1000/ Body weight

Based on the assessment of VO_2 max the physical fitness level of the respondents is categorized (Varghese et. al., 1994) as follows :

Physical Fitness level	**VO_2 max (ml/min)**
Poor	upto 15
Low average	16-25
High average	26-30
Good	31-40
Very good	41-45
Excellent	Beyond 45

3. **Rating of Perceived Exertion (RPE):** Workload in any task can be estimated through heart rate data but it is often difficult to measure it in a task of very short duration. To obviate this difficulty scientists recommended the use of another simple subjective method i.e. Rating of Perceived Exertion (RPE) for providing equally reliable information for the assessment of workloadsand its effects on the body as a whole.

For the present study the RPE scale on a 5-point continuum given by Varghese et. al. (1994) was used. After a bout of work the construction workers were asked to rate the exertion perceived by them according to RPE scale. The scale generally evidences a linear relation with both heart rate and oxygen uptake during work. According to Varghese et. al. (1994) the physiological work load corresponds with the energy expenditure and heart rate of the person and is as follows:

RPE Score	**Physiological Workload**	**Variables of Physiological Cost**	
		Energy Expenditure (Kcal/min.)	**Heart Rate (beats/min.)**
1	Very light	up to 5.0	up to 90
2	Light	5.1 – 7.5	91 – 105
3	Moderately heavy	7.6 – 10.0	106 – 120
4	Heavy	10.1 – 12.5	121 – 135
5	Very heavy	12.6 – 15.0	136 – 150
>5	Extremely heavy	> 15.0	> 150

4. Data collection and analysis: Data collection was done by the investigator personally using interview schedule. The data on background information, work profile, postures and exertion perceived were put to suitable statistical analysis to draw results i.e. mean percentages and standard deviation were calculated for the data obtained. The postures were analyzed using photographs.

III. RESULTS AND DISCUSSION

Background information of the respondents

Table 1 shows the personal characteristics of the respondents. Workers between the age of 17 to 42 were found working in construction industry. The mean age, height, weight of the respondents were 26.46±0.92, 159.63±2.92, 50.43±1.71 respectively.

Table 1 : Personal characteristics of the respondents

Variable	**Skilled (n = 30)**			**Unskilled (n = 30)**			**Total (n=60) Mean±S.D.**
	Min.	**Max.**	**Mean±S.D.**	**Min.**	**Max.**	**Mean±S.D.**	
Age (yrs.)	19	42	25.23±0.86	17	41	27.7±0.98	26.46±0.92
Height (cm)	152	175	162.36±1.23	151	170	156.9±4.61	159.63±2.92
Weight (kg)	40	75	51.93±1.90	35	70	48.76±1.53	50.43±1.71

The data showed that more than half of the respondents' i.e.63.33 per cent were from schedule tribe. Equal number of respondents (6.68 %) from both the categories i.e. unskilled and skilled, belonged to general caste, while 33.33 per cent unskilled and 26.67 per cent skilled respondents were from schedule caste. The data also revealed that an equal percentage of respondents i.e. of 53.33 per cent of skilled and unskilled respondents were having small families. Approximately 12 per cent of the total respondents were from large families. Remaining 35 per cent respondents had medium size of family.In total 51.67 and 48.33 per cent skilled and unskilled respondents were from joint and nuclear families respectively.

Maximum number of the respondents in unskilled category i.e. 63.33 percent could read and write, 3.34 per cent respondentswere educated up to middle level and others were illiterate. In skilled category 33.33 per cent of respondents could read and write whereas 23.33 per cent respondents had education up to primary level, 26.66 per cent in skilled category were educated up to middle leveland others had education up to high school level.

The monthly income of the respondents indicated that approximately 37 per cent of construction workers earned Rs. 4001-5000 monthly whereas 40 per cent of the total respondents had monthly income of Rs.

5001-6000. Only 30 per cent of skilled and 6.66 per cent of unskilled category respondents earned monthly income of Rs. 6000 or more.

2. Activity profile of the respondents

Activities performed by the worker is one of the ways of assessing the workload. It helps to know the extent of strain experienced by the person that may lead to body discomfort and exertion. It will help to formulate work-rest pattern for the workers with a view of minimizing fatigue and optimizing efficiency and productivity.The type of construction activities performed by the unskilled and skilled workers is depicted in Table 2.

It can be concluded from the data that maximum number of skilled respondents were engaged in finishing work such as plastering of walls, electrical fitting, roof layering and stone cutting work. The unskilled respondents were engaged in digging earth, mixing concrete, sand, cement, help in brick layering, stone cutting, fitting and polishing work.

Table 2: Type of construction work performed by workers

S.No.	Types of Construction work	Unskilled (n= 30)		Skilled (n=30)	
		F	%	F	%
1.	Digging Earth	4	13.33	0	–
2.	Carrying material	4	13.33	1	3.33
3.	Mixing concrete/sand, cement	3	10.00	0	–
4.	Brick layering work	4	13.33	1	3.33
5.	Stone cutting and fitting	4	13.33	4	13.33
6.	Tiles/Sanitary fitting work	2	6.64	2	6.64
7.	Finishing work, plastering etc.	4	13.33	10	33.20
8.	Roof laying	1	3.33	4	13.33
9.	Electrical fitting	2	6.64	6	20.00
10.	Polishing floor	2	6.64	2	6.64

It was evident from the data that 23.33 per cent of the skilled and unskilled respondents were involved in construction work since 16-20 years. Years of experience of the respondents ranged between one to thirty two years with mean years of experience of 7.96±1.56 for both the skilled and unskilled workers. Approximately 68 per cent of the respondents performed the construction task dailyfor 9 hours with one hour for lunch. The data also revealed that 50 per cent unskilled and 63 per cent skilled respondents performed the work of construction for 21-25 days in a month and 25 per cent of the total respondents worked for 15-20 days.

The data revealed that 75 per cent of the respondents carried load on their head whereas 30 per cent and 16.7 per cent of unskilled respondents carried load on shoulder respectively. The amount of load carried by the respondents wasapproximately 30-40 kg of weight while transporting pebbles, bricks, excavation material, for masonry work 10-20 kg of material was carried, while lifting material 16-30 kg of load was transported and when work such as drilling, concreting, wetting etc. was done load upto 15 kg was held by the workers.

3. Physical health assessment of construction workers :

Various parameters such as Body Mass Index, Body type and VO_2max has been used in the present research to find the physical health of the respondents. These parameters are based on the height and weight data of the subjects.

a) Body Mass Index of the respondents

Table 3 indicates the categorization of respondents according to Body Mass Index. Data reveals that approximately 37 per cent of respondents were in the category of low weight normal 26.67 per cent and 20 per cent of unskilled and skilled workers respectively were in the category of CED grade III which indicates severe energy deficiency. Only 25 per cent of the total respondents were in normal category of BMI.

Table 3: Distribution of respondents according to their Body Mass Index

Body Mass Index Range	Unskilled (n=30)		Skilled (n=30)		Total (n=60)		Health Risks
	F	%	F	%	F	%	
* CED grade III (Severe) <16.0	8	26.67	6	20.00	14	23.34	Risk of developing problems such as nutritional deficiency and osteoporosis
* CED grade II (Moderate) 16.0-17.0	2	6.67	2	6.67	4	6.67	
* CED grade I (Mild) 17.0-18.5	0	0.00	3	10.00	3	5.00	

Low weight normal 18.5-20.0	11	36.66	11	36.66	22	36.66	Low Risk (healthy range)
Normal 20.0-25.0	7	23.34	8	26.67	15	25.00	
Obese Grade 25.0-30.0	2	6.66	0	00.00	2	3.33	Moderate risk of developing heart disease, high blood pressure, stroke, diabetes
Obese grade II >30.0	0	0	0	0	0	0	High risk of developing heart disease, high blood pressure, stroke, diabetes
Mean ± **S.D.**	**19.34±0.55**		**19.46±1.51**		**19.4±1.03**		

* CED – Chronic energy deficiency

Thus, from the data it can be concluded that approximately 50 per cent of the construction workers do not possess good BMI ranges and may have risk of developing certain diseases due to nutritional deficiency, heart disease, high blood pressure, stroke or diabetes etc.Researchers have shown that both high BMIs and low BMIs can increase morbidity and mortality. A low BMI, usually an indication of protein-energy malnutrition or disease process, is a significant predictor of mortality. A high BMI has been shown to be predictive of mortality, usually an effect of cardiovascular disease and obesity.

Based on the BMI ranges the respondents' body type can be found. The data revealed that more than half of the respondents i.e. 60.00 per cent were having mesomorph type of body and 43.34 per cent unskilled and 33.33 per cent skilled workers were having ectomorph type of body while 3.33 per cent respondents had endomorph body type. This shows that most of the respondents have athletic type of body with well-developed musculoskeletal system.

b) Aerobic capacity (VO_2Max) of the respondents

Aerobic capacity i.e.VO_2Max is the maximum amount of oxygen that can be absorbed, transported and utilized during a given physical activity. It is normally expressed relative to body weight (ml of O_2 per kg body weight) (ml/kg/min.).

Table 4: Distribution of respondents according to their VO_2 Max

S. No.	VO_2 Max (ml/min.)	Physical Fitness Level	Unskilled (n=30)		Skilled (n=30)		Total (n=60)	
			F	%	F	%	F	%
1.	up to 15	Poor	2	6.66	5	16.66	7	11.66
2.	16-25	Low average	1	3.33	6	20.0	7	11.66
3.	26-30	High average	6	20.00	4	13.33	10	16.70
4.	31-40	Good	11	36.66	11	36.66	22	36.66
5.	41-45	Very good	5	16.67	2	6.67	7	11.66
6.	beyond 45	Excellent	5	16.67	2	6.67	7	11.66
Mean ± S.D.			**38.16±1.16**		**32.40±1.34**		**35.28±1.25**	

The data in Table 4 reveals that the VO_2 Max of 36.66 per cent unskilled and skilled respondents was between 31-40 ml/min. which indicate that they were having good physical fitness and 11.66 per cent were in each category i.e. poor, low average, very good and excellent. VO_2 max of approximately 17 per cent of the respondents was between 26-30 ml/min showing that their physical fitness level was in high average category. Thus, it can be concluded that the aerobic capacity of majority of the respondents was high average to good indicating their good cardio respiratory fitness.

4. Posture analysis of the construction workers

Posture is the position in which an individual hold his body. Poor posture puts pressure on the spine and the muscles get fatigued bringing discomfort, joint stiffness and pain. The posture of the respondents in various activities was analyzed for determining the long term health effect on the worker as it may lead to injuries of the back, neck, shoulders, arms and other body parts.

Table 5: Posture used by the respondents while performing work

S. No.	Posture Used	Unskilled (n=30)		Skilled (n=30)		Total (n=60)	
		F	%	F	%	F	%
1.	Standing	–	–	3	10.00	3	5.00
2.	Sitting/Squatting	2	6.66	5	16.66	7	11.66
3.	Bending	1	3.34	1	3.34	2	3.34
4.	Combination of two or more postures	27	90.00	21	70.00	48	80.00

The data in Table 5 shows that maximum number i.e. 80 per cent of the total respondents performed the activity in combination of posture such as sitting, standing, bending and squatting. The data regarding frequency of change in posture reveal that the posture was changed twice in every five minutes duration by 43.33 per cent of the respondents and by approximately 23 per cent of the respondents changed of the posture thrice in every 5 minutes duration.Li and Lee (1999) in their study on posture analysis of construction workers found that more than 30 per cent of the working postures observed were classified as slightly harmful, distinctly harmful or extremely harmful.

Posture for various construction activities performed by the workers put certain amount of stress and strain on human body. The muscles, joints, spine and internal organs all are affected by the posture. In Table 6 an attempt has been made to comprehensively show the posture of all the construction activities along with their possible impact on the health of the worker.

Table 6 :Posture analysis of the respondents performing construction activities

Activity	Motion	Workers Posture	Possible impact on health
Stone Cutting and Brick layering work	Flexion of pelvic and knee joints, extension of hands	Squatting and Bending	Muscle spasm, stiffness, cervical and lumbar spondylosis and trapezius myalgia
Flooring Work	Flexion	Squatting	Carpal Tunnel syndrome, sciatica pain, strain on muscles of thighs and knee, cervical and lumbar spondylosis
Material Handling	Flexion	Bending	Cervical and lumbar spondylosis, neck stiffness, bicipital tendonitis, thigh and calf strain
Mixing Concrete	Flexion	Bending	Bicipital tendonitis, tennis elbow, cervical and lumbar spondylosis, neck stiffness
Carrying Load	Extension	Standing	Headache, trapezius myalgia, strain on neck and arms muscles, joint pain, thigh and calf strain
Plastering of walls, electrical work	Extension	Standing	Trigger finger, joint dysfunction, tendonits of the wrist, rotator cuff tendonitis of shoulders
Finishing, tile and sanitary fitting work	Flexion	Standing	Lumbar spondylosis, strain on back muscles, trigger finger, tendonits of the wrist, rotator cuff tendonitis of shoulders
Machine work, floor polishing with machine	Flexion	Standing and Bending	Myofascial pain disorders, hand-arm vibration syndrome, muscle and joint pain, tendonitis of forearm and wrist and trapezius myalgia

Thus, it can be concluded that poor postures have negative effects on health of the worker and poses many musculoskeletal problems to the workers who are regularly engaged in construction activities.

5. Rating of Perceived Exertion of the respondents

Perceived exertion has been characterized as the perception of the effort sensations experienced during completion of a physical task. Abnormal posture at work is one of the causes of exertion and fatigue. The researchers recommend measuring perceived exertion which shows the feeling of a person about the activity performed.

Table7 : Rating perceived exertion of the respondents

S. No.	Rating perceived Exertion (RPE)	Unskilled (n=30)		Skilled (n=30)		Total (n=60)	
		F	%	F	%	F	%
1.	Very light	–	–	–	–	–	–
2.	Light	4	13.34	5	16.66	9	15.00
3.	Moderately heavy	5	16.66	12	40.00	17	28.34
4.	Heavy	15	50.00	11	36.67	26	43.33
5.	Very heavy	6	20.00	2	6.67	8	13.37

The data depicted in Table 7 reveal that the construction activity performed by the respondents was perceived as heavy by 43.33 per cent of the respondents whereas approximately 28.34 per cent perceived it as moderately heavy, 13.33 per cent perceived the activity as very heavy.

Researchers have indicated that RPE is a reliable indicator of an individual's activity tolerance. It is highly correlated with heart rate and thereby physiological work load. ThusRating of Perceived Exertion can

be used to prescribe the work load of a person and also to monitor the intensity of work. Data regarding endurance of pain during or after work showed that 55 per cent of the respondents reported pain in various parts of the body after work, 20 per cent of the respondents revealed that the pain was apparent while doing the work only and 15 per cent respondents reported that the pain continued for a longer time after work. Ten per cent of the respondents felt pain in various parts of the body if another work is done in the same posture.

6. Ergonomic guidelines for the construction workers

It is estimated that 54% of all construction injuries/illnesses are ergo-related. Some of the most common injuries in construction are the result of job demands that push the human body beyond its natural limits. Workers often lift, stoop, kneel, twist, grip, stretch, reach overhead, or work in other awkward positions to do a job and are thus at risk of developing work-related musculoskeletal disorder (WMSD). These can include back problems, carpal tunnel syndrome, tendinitis, rotator cuff tears, sprains, and strains. The best way to reduce WMSDs is to use the principles of ergonomics to redesign tools, equipment, materials, or work processes.

Ergonomics is a safety science of how a person interacts with their work and their work environment which is very important to both health and safety. When ergonomic changes are introduced into the workplace or job site, they should always be accompanied by worker training on how to use the new methods and equipment, and how to work safely.

Ergonomic tips to minimize awkward postures and hazards during construction work were given for work methods, work environment and for workers safety. For work methods they were advocated to work near elbow height to avoid excessive bending, avoid overhead reaching when possible, standing on a stool, ladder to work into a safer position. If tasks require work at lower surfaces, sitting on a stoolcan minimize crouching.Shift positions very often and using proper techniques when lifting heavy materials. Practice proper cart handling, push instead of pulling, use both hands when pushing, job rotation, short breaks between heavy tasks, etc.

For working tools/equipment select hand tools that confirm to the geometry of the hands. Avoid handles that end in the palm of the hand.Avoid manually handling heavy objects (more than 35 pounds) and avoid carrying objects more than 100 feet. Use vibration damping (gel filled) gloves and power tools when available in repetitive tasks. Change tasks, stretch, or take a break from the task that require prolong use of same tool or machine.

Suggestions were given to the workers to plan their work to alternate kneeling with standing in order to stay productive while giving tired muscles a break. Avoiding prolonged awkward postures to avoid static loading of muscles. Change the position of the work or the body position to get as close as possible to the work area.If prolonged awkward postures are unavoidable, use a "supported" posture to compensate. Perform tasks with two hands rather than one when possible. Work with wrists straight, not bent.Avoid pressure on knees, palms, wrists and elbows. Use padding on hard or sharp surfaces. Change your position to eliminate the stress. Make use of Personal Protective Equipment whenever possible. Wearing of helmets and gloves to avoid injuries.Always wear shoes and boots which are slip-resistance during work. Workers should use ear protection devices when working on machines that create noise of more than 90 dB. Do not drink or take drugs while working.

Work environment should be conducive. Work areas must be well lit. The site should be kept clutter free especially the areas where the work is being carried out. Roof openings at heightsshould be fenced or covered. Safe, non-slippery ladders/ equipment must be used for the tasks. Avoid using ladders with metallic components near electrical work and overhead power lines. Building material should be piled, stacked or racked in such a way that prevents it from tipping, falling, collapsing, rolling or spreading.

IV. CONCLUSION

Construction workers are the backbone of the Indian economy as they create the infrastructure necessary for industrial growth. It is basically a labour intensive industry and employs nearly 3.4 corer people in India. Construction workers in India on an average work for 8-9 hours a day and perform arduous activities. They are prone to many problems related to health and musculoskeletal due to awkward postures, heavy, repetitive and forceful work. During work the workers adopt postures like bending, standing, stopping, and squatting. Moreover these postures are maintained for long duration which leads to fatigue and body pain. Compatibility between the construction workers and the work environment can be brought about by the use of Ergonomics. In the present research approximately 25 percent of the skilled and unskilled respondents were involved in house construction work since 16-20 years.The results of the physical health status revealed that approximately 37 percent of the respondents were in the category of low weight normal and only 25 percent of the total respondents were in normal category of BMI.Based on the VO_2 max data only 37 percent of the respondents were having good aerobic capacity. The exertion perceived by respondents was heavy which was reported by approximately 43 percent of the respondents whereas approximately 28.34 percent perceived it as moderately heavy. Thus, we can conclude that

the types of work, poor and awkward work postures have an impact on physical health and body discomfort and musculoskeletal system by the worker. Good health has long been acknowledged as one of the most critical element to quality of life. The health of workers is a vital resource to protect. Compatibility between the construction workers and the work environment can be brought about by the use of Ergonomics.Ergonomic recommendations were given to the respondents with a view to promote their well-being and consequently improve their quality of life.

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