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Effect of Automation on Different Ergonomic Parameters in Traditional Millet Production

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ABSTRACT

Women play an important role in post-harvest operations of millets and being labor-intensive using traditional methods leads to drudgery. The study examines drudgery and the impact of the adoption of selected improved practices based on ergonomic parameters over traditional practices. A purposive random sampling method was followed and a total of 112 women farmers of on millets were selected from Chalki and Gangapur villages in Sangareddy district of Telangana state. Data were collected directly from the farm women using pre-tested interview schedules and analysed using suitable statistical tools. There was a significant correlation found between the drudgery index in traditional practices and with physical profile of the women like age, height, and body mass index. With the increase in the age of the farm women, their strength in performing traditional practices becomes weak. Fifty percent of women felt that it was very easy to prepare flatbread using a power-operated flatbread machine. The drudgery in flatbread making was found to be reduced to moderate (58.51) and minimum (less than 50) levels and the same was in the four operations. Increased work output, reduced drudgery (35-88%) and time (31-90%), and minimized postural discomfort (moderate to very light pain) were recorded while using improved practices by them. Reduction in drudgery and time due to the use of improved practices resulted in postural comfort and reduced health issues concurrently, while leading to an increase in their income, millet consumption, and overall livelihood status. Designing improved tools, equipment, or work methods that should take the ergonomic and physical characteristics of women into account can help to lessen drudgery, especially in traditional millet production areas.

Keywords: Drudgery index, millets, traditional practices, improved practices, postural discomfort, farm women, automation, ergonomic, difficulty of operations, post-harvest practices.

INTRODUCTION

Women play a vital role in a broad range of agricultural activities such as production processing, preservation, and utilization of food by feeding the family from harvested produce as well as in domestic management of its allied activities. Women work longer and harder than men which causes a lot of physical strain [7]. Due to the labor-intensive nature of millets where women play a crucial role in off-farm production and processing of millets, this is one of the reasons why millets were being given up in favour of male-preferred cash crops [9]. Women in rural areas are still using traditional or age-old methods of post-harvest operations in millets which require them to work in inappropriate working postures for long hours and monotonous which leads to drudgery and physical strain.

Drudgery is generally conceived as physical and mental strain, fatigue, monotony, and discomfort experienced while performing a task. To overcome both physiological and psychological drudgery, the use of improved tools was found to be economically viable and superior in terms of reducing drudgery [12]. The lack of mechanization in this area puts an extra burden on women, increasing the drudgery level that in

turn affects their nutritional status and health [5]. If appropriate drudgery-reducing methods or equipment are made available, they increase productivity, and women's capability and consequently thereby, improve efficiency [7]. There is a specific need for gender-friendly/ responsive tools that are ergonomically designed for women farmers in post-harvest operations of millets. The drudgery perception of women about post-harvest operations of millets helps to deal with ergonomic issues in the development of such tools and implements. For better understanding, it is also important to know how women participate in various operations and how their physical profile affects drudgery. Worldwide number of studies have been done on this aspect in various crops but very few studies have been reported on millets. Thus, this study was contemplated to assess the effect of improved practices including power-operated machines and technologies, on different ergonomic parameters compared with traditional practices, and to measure the extent of discomfort of women farmers by estimating drudgery parameters given reducing their drudgeries.

MATERIAL AND METHODS

The study was carried out in Sangareddy district of western Telangana state of India. Two villages, Chalki and Gangapur were purposively selected as the women were intensely involved in millet production in the district. A sample of 112 women farmers were selected who represented the active involvement under millet post-harvest practices. Randomly, 56 women farmers each from the village were selected to ascertain

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the intensity of workload among the sample of women farmers. Five post-harvest operations namely; threshing, drying, winnowing, flour milling, and flatbread (*roti*) making were identified as high-drudgery prone operations and thereby, ergonomically evaluated in comparison with power-operated machinery (or improved practices) and traditional practices. A conceptual framework for this study is developed using an extensive literature review representing the relationship between various parameters (Fig.1).

The primary data were collected on profile parameters, the amount of time spent by the respondent in a particular operation, the frequency with which the operation was repeated during the complete production cycle, and the perceived difficulty of the operation using a pre-structured interview schedule based on the framework of the study. The data were analyzed using suitable statistics of frequency and percentage. The variable workload was recorded as time spent in a particular activity in hours per day, frequency of performance assigning daily, weekly, monthly, seasonally, and annually with a score of 1, 2, 3, 4, and 5, respectively, and the difficulty of operation was measured assigning very easy, easy, neutral, difficult & very difficult with a score of 1, 2, 3, 4 & 5, respectively were scored on a 5-point continuum, as followed by [14] with slight modifications. Body posture adopted was categorized *viz.* upright, trunk flexion/extension (0-200), trunk flexion extension (200-600), and trunk flexion-extension (>600) as done [13]. The postural discomfort was measured using a 10-point psychophysical rating scale called the Overall Discomfort Scale (ODR) (0= no discomfort and 10= extreme discomfort) [2]. The drudgery for each activity was estimated based on weighted averages like average time spent in minutes, frequency of performance, and difficulty of operation perceived by the respondent while doing the farm activity and using the drudgery index which was followed by [6]; [11]. The drudgery index for an activity was simplified for each individual. The overall or average drudgery of a person was computed by taking the average of all drudgery indices related to selected post-harvest operations.

Drudgery index of j^{th} respondent in i^{th} activity = $DI_{ij} = \{(X_{ij} + Y_{ij} + Z_{ij}) / 3\} \times 100$

Where,

$$X_{ij} = \frac{x_{ij}t_{ij}}{\sum_{i=1}^5 x_{ij}t_{ij}}; Y_{ij} = \frac{y_{ij}}{5}; Z_{ij} = \frac{z_{ij}}{5}$$

$i = 1(1)5; j = 1(1)n;$

n = Number of respondent

m_j = Number of activities performed by j^{th} respondent

x_{ij} = Average time spent in minutes in a day by j^{th} respondent in i^{th} activity

t_{ij} = Number of days j^{th} respondent performed i^{th} activity

y_{ij} = Relative score related to frequency of work for j^{th} respondent in i^{th} activity

z_{ij} = Relative score related to degree of difficulty for j^{th} respondent in i^{th} activity

RESULTS AND DISCUSSION

Physical characteristics: Results (Table 1) of anthropometric data of selected women farmers indicated that most of the women who performed post-harvest operations in millets were of middle age (25-56). As per the Indian Council of Medical Research (ICMR) classification, the average BMI of women was classified as normal weight but their range was between underweight to obesity grade I [3] which avoids any bias during data collection in drudgery parameters.

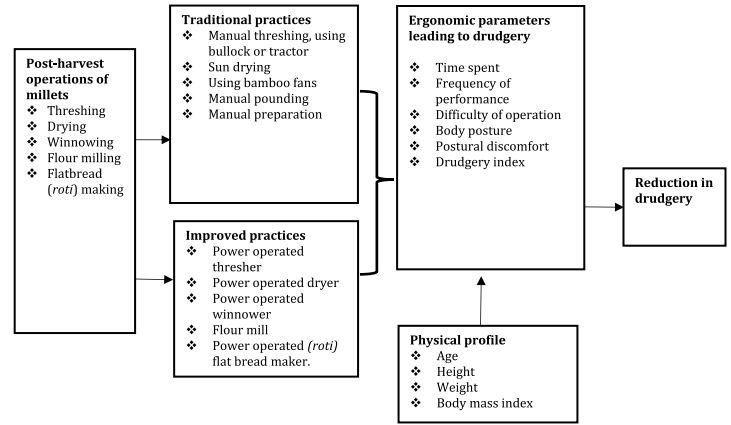


Fig.1 Conceptual framework of the study

Table 1. Physical characteristics of women farmers

Physical characteristics	Range	Mean
Age (years)	25-56	37
Height (cm)	145-172	156
Body weight (kg)	45-66	52.7
BMI (cm)	16.2-29.5	21.96

Time spent: Time spent (h/day) on post-harvest operations revealed (Table 2) that the average time spent on threshing, drying, and winnowing using improved practices reduced the time of approximately 3 h/day when compared to traditional practices. The findings were similar to [9]. Farm women contribute about 10-12 hours in agriculture and allied fields and at least 4 hours in household chores [14]. Among agriculture activities, the average time spent by women in harvesting and post-harvesting activity was 7.98 h/day. According to [14], threshing alone takes 20 average man days per season. Hence, the results showed that the drudgery of work was reduced with the intervention of automation (improved practices) while saving time. Overall, improved practice could save time ranging between 31% and 90%, which was a great relief to them.

Table 2. Time spent for performing post-harvest operations (N=112)

Operation	IP (h/day)	TP (h/day)
Threshing	3.01	6.72
Drying	2.48	6.00
Winnowing	3.00	6.91
Flour milling	0.31	3.00
Flatbread making	2.04	2.95

IP = Improved practices; TP = Traditional practices

Frequency of performance: The frequency of performance of all the selected post-harvest operations showed that there was little to no change (Table 3). Post-harvest operations like winnowing, drying, and threshing were done seasonally, just once after harvesting. So, the amount of time that women spend doing productive work, in which the intensity of labor was reduced rather than the frequency of performance. Women farmers stated that they typically used to pound the grains to make flour whenever they needed little quantity because it took a lot of energy and hurt their lower back and shoulders when it was done for extended periods. However, with improved practices, even though they did it weekly or seasonally, the number of days required to produce flour in a year was cut down to 15-20 days, and that too in higher quantities. This was the same case with the other post-harvest operations also. This gave them more time to spend with their families and pursue other interests.

Table 3. Frequency of performing post-harvest operations (N=112)**

Operation performed	Traditional practice	Improved Practice
Threshing	Seasonal (100)	Seasonal(100)
Winnowing	Seasonal (100)	Seasonal (100)
Drying	Seasonal (100)	Seasonal (100)
Flour milling	Weekly (69), Seasonal (31)	Weekly (53), Seasonal (47)
Flatbread (<i>roti</i>) making	Daily (100)	Daily (100)

Percentage are mentioned in parentheses, **Multiple responses

Difficulty of operation: Post-harvest operations in millets were predominantly dominated by women. Women spent significantly more amount of time doing this activity, thus causing muscle fatigue and drudgery. [7] reported that almost 70% of women felt harvesting and post-harvest activities as difficult activity. The introduction of improved practices made a difference by reducing the difficulty of performing the

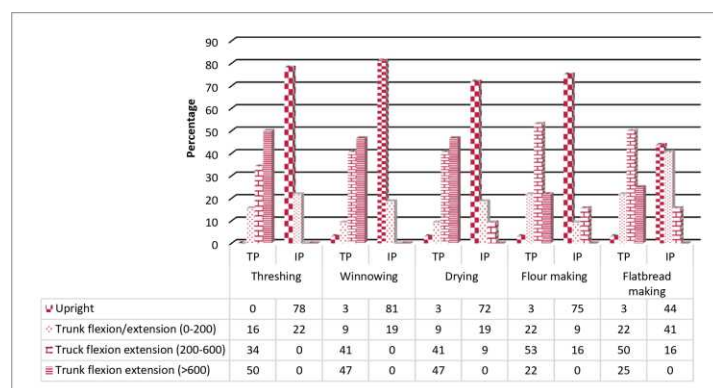
Table 4. Difficulty felt in performance of the post-harvest operations (N=112)**

Categories		Operation performed				
		Threshing	Winnowing	Drying	Flour milling	Flatbread (<i>roti</i>) making
Very easy	TP	-	-	-	-	-
	IP	-	-	-	32 (100)	-
Easy	TP	-	-	-	-	-
	IP	9 (28.1)	9 (28.1)	32 (100)	-	16 (50.0)
Neutral	TP	2 (6.2)	-	-	-	-
	IP	19 (59.3)	19 (59.3)	-	-	16(50.0)
Difficult	TP	8 (25.0)	14 (43.7)	11 (34.3)	-	-
	IP	4 (12.5)	3 (9.3)	-	-	-
Most difficult	TP	22 (68.7)	18 (56.2)	21 (65.6)	32 (100)	32 (100)
	IP	-	1 (3.1)	-	-	-

Percentage are mentioned in parentheses, **Multiple responses

Body posture adopted: A person with good posture can complete tasks more efficiently and with the least amount of pain in their muscles by requiring little static effort. Using traditional practices for lengthy periods with awkward and improper working postures led to drudgery [1]; [15]. Results (Fig.2) revealed that almost half of the respondents (50%) used trunk flexion-extension (>600) posture while threshing, winnowing, and drying, and trunk flexion-extension (200-600) posture when making millet flour and flatbread under traditional practices. Women farmers reported experiencing discomfort in many body parts, with the most severe pain in their lower back, after executing these operations in bending and squatting positions for an extended period using traditional methods. Postures, particularly those involving severe flexion or lateral twisting and bending, were linked to lower back pain [10]. When respondents (more than 70%) performed post-harvest operations using improved practices, they did not have to bend or squat, which significantly reduced their pain. As preparing flatbreads requires preparing dough while seated, 41% of the female respondents used trunk flexion-extension (<200) posture, however, they claimed that because it took less time to prepare flatbreads (*rotis*) using a flatbread (*roti*) maker and it was less painful than the traditional practice.

operations. Results (Table 4) revealed that more than fifty percent (56.2%) of women felt winnowing was the most difficult operation while most (59.3%) felt the difficulty became neutral using winnower. In the study conducted by [11], the majority (64.28%) of women reported that winnowing was the most difficult operation compared to 26.38% of men. Among all operations, women farmers unanimously expressed that flour milling and flatbread making were very difficult operations and time-consuming in traditional practice. While using flatbread makers, 50% of women said it was very easy to make flatbreads (*rotis*). The reason they felt that way is because in millets traditional post-harvest operations require high human energy which includes a lot of physical strain and fatigue in women farmers. This could increase the risk of work-related musculoskeletal disorders in the long run.

**Fig.2 Body posture adopted by respondents while performing post-harvest operations (%)**

Postural discomfort: Discomfort is body pain arising as a result of the working posture and/or the excessive stress on muscles due to the effort involved in the activities. Post-harvest operations in millets are time-consuming as they are performed for hours together continuously. These results in musculoskeletal problems while adopting awkward and uncomfortable postures and carrying excessive loads which has been observed to have a great impact on the health of women farmers.

Therefore, musculoskeletal problems and posture were evaluated by asking women farmers where they felt pain in their bodies after performing each of the post-harvest operations. Results (Fig.3) showed that while threshing with the help of a machine, the postural discomfort levels were limited to moderate pain (88%). During threshing, women reported that very severe and severe pain in the upper back was experienced by 50% of respondents whereas 40% reported moderate pain [16]. The majority (47%) of the women were suffering from very severe pain in their limb joints when winnowing was done manually with traditional practice. However, while using a power-operated winnower with the help of the blower, they felt less pain along with minimum work hours (81%).

Making flour for flatbread (*roti*) preparation using a stone grinder caused moderate back pain in the women (56%), it was mainly based on the quantity of grain to grind and more working hours. Most of the women were slow in flatbread preparation those who were not much experienced. They felt moderate difficulty in their posture setting but, after using a flatbread (*roti*) making machine, 63 percent of women got command of the skill for making flatbreads (*roti*) and minimizing the time which led to controlling their drudgery level. Working in bending and squatting posture, repetitive motions, and excessive force applied for longer periods might be the reason that almost all the women reported severe discomfort in the lower back, knees, upper back, ankle, knees, feet, and neck. These findings were similar to [2].

Drudgery index: Drudgery is defined as dull, repetitive, time-consuming, irritating, and fatigue-causing work [8]. It was also stated that excessive labor, improper posture, and time spent at work were the main contributors to drudgery in agriculture. Except for drying, which was prone to moderate drudgery (DI=69.40) (Table), it was evident (Table 5) that all the selected post-harvest operations of millets using traditional practices were susceptible to maximum drudgery (DI more than 70). Even though drying takes a long time to ensure uniform drying, which leads to weariness, it involves less repetitive effort than other

procedures, and women could take regular breaks. All operations involving power-operated machinery resulted in a reduction in the drudgery index to a minimum (DI less than 50), except the flatbread (*roti*) making, which reduced to moderate drudgery (DI = 58.51) (Fig.4). The explanation for this could be that dough preparation was rather drudgery-inducing. Aside from that, women farmers stated that the adoption of automated machinery (or improved methods) reduced drudgery significantly, as well as the total load of work and home duties. The findings were in contrast to those of [11] where women laborers perceived weeding, land preparation, and pesticide application are highly drudgery-prone activities. It reasons for contrast could be related to the small grain size of millets, which complicates traditional post-harvest activities and can result in grain loss if not performed carefully. It's partly because men were more focused on producing activities while post-harvesting was generally taken up by women's domain in millets. This eventually increases drudgery in women, which might lead to musculoskeletal injuries and/or disorders in the long run.

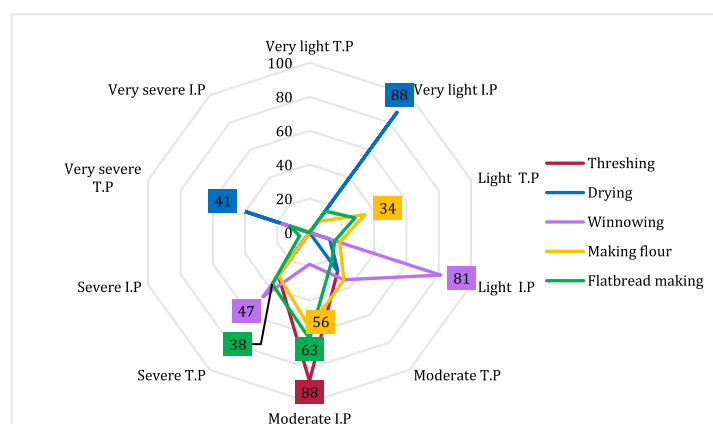


Fig. 3 Postural discomfort while performing post-harvest operations in millets

Table 5. Drudgery index of the selected post-harvest operations of millets** (N=112)

Operation performed		Time co-efficient	Difficulty co-efficient	Frequency performance co-efficient	DI	Remarks
Threshing	TP	0.84	0.93	0.40	72.16	Max.
	IP	0.38	0.57	0.40	44.84	Min.
Winnowing	TP	0.86	0.91	0.40	72.52	Max.
	IP	0.38	0.58	0.40	45.00	Min.
Drying	TP	0.75	0.93	0.40	69.40	Moderate
	IP	0.31	0.40	0.40	37.01	Min.
Flour milling	TP	0.38	1.00	0.74	70.41	Max.
	IP	0.04	0.40	0.71	38.16	Min.
Flatbread making	TP	0.37	1.00	1.00	78.97	Max.
	IP	0.26	0.50	1.00	58.51	Moderate

Max- Maximum, Min-Minimum, **Multiple responses

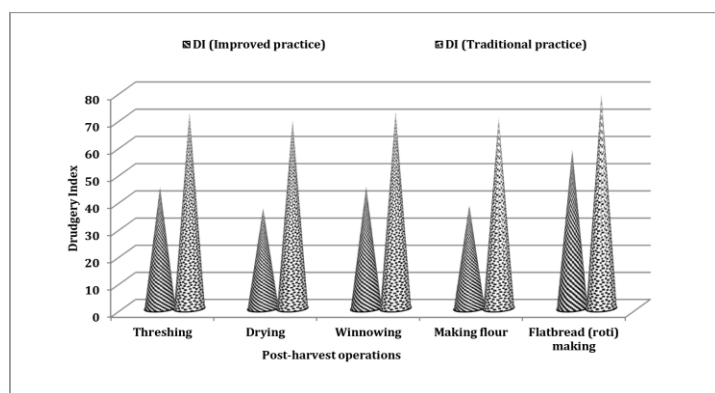


Fig. 4 Drudgery index of the selected post-harvest operations of millets

Drudgery reduction with improved practices over traditional practices:

Research revealed that there was a significant relationship between the five identified post-harvest operations and the women farmers' postural discomfort and the drudgery index at the 0.05 percent significance level when they performed them using traditional practices (Table 6). It shows that significant levels of drudgery and postural discomfort are involved while performing these post-harvest operations traditionally. Women used to spend a lot of time and effort in the initial processing of millet, particularly in the grinding, pounding, and winnowing of the grains. Results from this study also showed (Table 6) that selected post-harvest operations are drudgery-prone, often causing severe to very severe postural discomfort or pain. To manage the conflicting needs of agricultural production, household duties, and income generation; there is a specific need for women-friendly tools in the study which should not be heavy, distort the correct postures, and reduce the workforce [14]. It is important to consider and value energy conservation, level of drudgery, time, and postural discomfort faced by women while designing automated machinery or improved practices in post-harvest operations of millets.

Table 6. Relationship between traditional post-harvest operations and drudgery reduction

Post-harvest operations	Drudgery index (t-test value)	Postural discomfort (t-test value)
Threshing	20.58**	7.87**
Winnowing	20.09**	11.36**
Drying	41.02**	18.90**
Flour milling	39.95**	3.12**
Flatbread making	27.28**	3.19**

** significant at 0.05 level of significance

Table 7. Correlation between drudgery index in traditional practices with a physical profile of respondents

Independent variable	Drudgery index of traditional practice (r values)				
	Threshing	Winnowing	Drying	Flour milling	Flatbread making
Age	0.821***	0.605***	0.452***	-0.501**	-0.657***
Height (cm)	-0.443*	-0.477**	-0.272	0.52**	0.51**
Weight (kg)	-0.028	0.026	0.254	0.003	0.107
BMI	0.32	0.404*	0.438*	-0.385*	-0.287

*Significant at 0.05 level

**Significant at 0.01 level

***Significant at 0.001 level

Apart from ergonomic parameters, the physical profile of women also plays a significant role in body capacity and health status which reflects their drudgery level. To understand how the physical characteristics of women farmers affect drudgery while performing traditional practices, a correlation analysis was done. Results (Table 7) revealed that age was found to have a significant correlation with all selected post-harvest operations of millets. In operations like threshing, winnowing, and drying which require long standing periods and awkward and repetitive postures, as age further increases, it leads to a decrease in muscle mass and a reduction in strength leading to a higher perception of pain by women. While the negative and significant correlation between drudgery involved in flour ($p = -0.501$) and flatbread making ($p = -0.657$) with age shows that with an increase in age, their experience in such activities also increases which was obvious as experience teaches how easily any work can be carried out and tends to commit fewer mistakes. In such cases, they can be introduced to improved practices which are easier and more efficient ways to complete the workload, reducing time of operation and drudgery. It may be difficult for tall women to perform flour and flatbread making as these operations involve bending and squatting postures (trunk flexion-extension 200-600 and >600) for a long time showing positive and significant correlations. While it can be advantageous when operations are performed in standing postures (*viz.* threshing, winnowing, and drying) but not for longer periods. The reason to no correlation found between weight and drudgery index of selected operations may be due to the average weight of women farmers was within the normal range (Table 1). The risk of MSDs amongst overweight/obese individuals was 1.7 times higher than non-overweight participants [10] which may be related to decreased muscular strength, weakness, and lowered physical activity [4]; [10]. There is a significant and positive correlation between BMI and drudgery involved while performing winnowing, and drying and a significant negative correlation while performing flour milling. [10] stated in their study that both underweight and overweight/obese as potential causes of MSDs in women farmers. Women farmers spent most of their time in activities that were non-mechanized and involved more drudgery. Therefore, designing improved tools, equipment, or work practices with due consideration of ergonomic as well as physical characteristics of women is accommodating to reduce drudgery.

The results showed that a considerable amount of drudgery was involved while performing post-harvest operations of millets under traditional methods which was reduced to a great extent using improved practices. So, there is an urgent need for the implementation of ergonomic interventions with proper awareness among agriculture farm women. However, the current study offers opportunities for further research refinements for developing energy-efficient, cost-effective, and women-friendly technologies and farm implements that can save time, labor, and energy. Women get limited opportunities to use modern technologies as they do not have the awareness and access to training required for performing operations using such technologies. Moreover, these technologies are not scaled up and have low adoption rates due to poor information and dissemination strategies at the local, regional, and national levels.

SCOPE OF THE STUDY

Women play an important role in maintaining the nutritional security of the family as well as most women tend to work longer and more fragmented days than men as they are usually involved in three different gender roles such as productive, reproductive and community work. The study examines drudgery in different post-harvest practices of millets, food preparation and the impact of the adoption of selected improved practices based on ergonomic parameters over traditional practices of millets. The study suggests opportunities for further research refinements for developing energy-efficient, cost-effective, and women-friendly technologies and farm implements that can save time, labor, and energy to ascertain the significant issues that need to be prioritized by the policymakers to make international year of millets more healthy, lucrative and attractive.

Conflict of interest

The authors declare no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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