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Original Research

The Relationship between Socioeconomic Status and Adherence to Antihypertensive Treatment Regimen in a Metropolitan Community Sample of Hypertensive African Americans in New York

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ABSTRACT

Introduction

Low socioeconomic status (SES) is one of the strongest predictors of morbidity and premature mortality worldwide, as well being associated with large increases in cardiovascular disease in both men and women. Uncontrolled hypertension contributes to cardiovascular disparity. Non-adherence to antihypertensive regimens worsens the cardiovascular burden and further widens the health disparity gap. A hierarchical multiple regression study of multiple factors impacting adherence among urban residents in a New York metropolitan region found socioeconomic factors as the strongest factors impacting adherence in this cardiovascular high-risk population..

Methods

Secondary analysis of data of a cross-sectional, correlation design study of a dissertation study, with each of the SES variables analyzed against adherence and self-efficacy variables.

Results

Overall, only three SES variables (years with the same provider, work status and income) were significantly related to adherence and/or self-efficacy. Years with the same provider was related to adherence with correlation of rs=0.16 (p=0.048), and to self-efficacy rs=2.0 (p=0.016). Work status was related to adherence with difference in adherence scores between retired and unemployed subjects (KS=38.6, p=0.013 with Bonferroni adjustment; means=3.7 and 3.3, respectively). Work status was not related to self-efficacy scores. Income level was significantly related to the self-efficacy scores, but not the adherence scores. Difference noted between earners<$10,000/year and >$80,000/year (KS=-44.2, p=0.037, with Bonferroni adjustment; means=3.06 and 3.51, respectively).

Discussion

Low socioeconomic status and non-adherence to antihypertensive regimens remain important factors which worsen cardiovascular health and widen health disparity health gaps. This is evident among the cardiovascular high-risk persons of African descent including those residing in the New York metropolitan regions. Self-efficacy is implicated as a mediating variable between income and adherence. The inverse relationship between fulltime work status and adherence was no longer noted. Further investigation on the associations between income, full time status and adherence among young, hypertensive Blacks/African Americans; as well as self-efficacy mediating effects on income and adherence is recommended.

Keywords

Socioeconomic status or poverty or low income; Adherence or compliance; Hypertension treatment or hypertension therapy; Blacks or African Americans.

INTRODUCTION

Low socioeconomic status (SES) is one of the strongest predictors of morbidity and premature mortality worldwide,[1] and associated with large increases in cardiovascular disease in both men and women.[2] With rising prevalence of many chronic disease risk factors, the global burden of cardiovascular diseases is expected to increase, particularly in the low- and middle-income countries where over 80% of all cardiovascular diseases (CVD) deaths occur.[3] In high-income countries, an inverse association between SES and CVD risk results from the high prevalence, and compounding effects of multiple behavioral and psychosocial risk factors in people of low SES. Psychosocial factors, inequalities in health services, and the influence of area of residence strengthen these relationships.[2] SES refers to a wide range of factors that affects the quality of health care a patient receives, and includes educational level, health literacy, income level, employment status, insurance status and ability to access care.[4,5]

Low social economic factors have long been linked to cardiovascular health disparity.[6] In the United States, disparities in racial and socioeconomic-related CVD mortality are noted between Blacks/African Americans and their racial counterparts. Between 1969 and 2013, CVD mortality rates decreased by 2.66% per year for whites and 2.12% for Blacks. In 2013, Blacks/African Americans had 30% higher CVD mortality than Whites and 113% higher mortality than Asians/Pacific Islanders.[3]

Hypertension is the strongest modifiable risk factor for CVD worldwide,[7] a global public health issue, and contributes to cardiovascular morbidity, premature mortality and disability.[8] Similar to other health disparities like obesity and diabetes mellitus, Blacks/African Americans have higher prevalence of hypertension, lower rates of controlled hypertension and higher incidences of hypertension-related morbidity and mortality than other ethnic groups.[9,10] For example, compared to Whites, Blacks/African Americans have a 30% greater rate of nonfatal stroke, 80% greater rate of fatal stroke, and a 420% greater rate of end-stage kidney disease.[11] The prevalence of hypertension in Blacks in America is the highest in the world; it develops at an early age, progresses quickly and is not easily controlled.[10] However, non-adherence is an increasing challenge.

Socioeconomic factors impact hypertension control with respect to diagnosis, treatment, and patient's access and long-term adherence to recommended treatment regimens, and studies suggest that patients with lower SES receive fewer preventive services, lower rates of use of evidence-based therapies, and fewer indicated interventions such as coronary angiography and organ transplantation.[12-14] The World Health Organization (WHO) Global Action Plan for the Prevention and Control of non-communicable diseases (NCDs) targets seven major health risk factors, including insufficient physical activity, current tobacco use and raised blood pressure, for reducing premature mortality from non-communicable diseases by 25% by 2025. Despite being one of the strongest predictors of morbidity and premature mortality worldwide, low socioeconomic status was not included among modifiable risk factors. Authors have suggested that socioeconomic adversity be included as a modifiable risk factor in local and global health strategies, policies, and health-risk surveillance.[14] Clinicians are advised to address the association between SES and CVD by incorporating SES into CVD risk calculations and screening tools; as well as reducing behavioral and psychological risk factors through effective primary and secondary prevention. In addition, multidisciplinary approaches to assess inequalities in healthcare delivery and outcomes through health equity audits are advised.[2]

In essence, socioeconomic status, uncontrolled hypertension and non-adherence to recommended hypertension treatment regimens seem to worsen the cardiovascular burden noted among the cardiovascular high-risk Black/African American groups, further widening the health disparity gap. Self-efficacy (also investigated in the parent study) has been found as an important, as well as mediating variable with respect to adherence to antihypertensive regimens among African American subjects.[15] This paper presents a secondary analysis of data of a recent dissertation study to further describe the noted strong relationships between socioeconomic factors and hypertension treatment adherence in persons of African descent residing in a metropolitan region of NY in the United States.[16] Self-efficacy variable (investigated in the parent study) will be included as an additional outcome variable to evaluate results.

A meta-analysis of 51 studies on socioeconomic status and hypertension published in English,[17] found an overall increased risk of hypertension among the lowest SES for all three indicators: income [pooled odds ratio (OR) 1.19, 95% confidence interval (CI) 0.96-1.48], occupation (pooled OR 1.31, 95% CI 1.04-1.64) and education (pooled OR 2.02, 95% CI 1.55-2.63). The associations between these variables were significant in high-income countries; the increased risk of hypertension for the lowest categories of all SES indicators was most evident for women, with men having less consistent associations.

In many countries, socioeconomic status and mortality have been found to be comparable. For example, data from more than 1.7 million individuals in 48 independent cohort studies from seven countries and found that the independent association between socioeconomic status and mortality is comparable in strength and consistency to those of six 25×25 risk factors (tobacco use, alcohol consumption, insufficient physical activity, raised blood pressure, obesity, diabetes).[1] This study was considered one of the largest studies to date to examine the association between socioeconomic status and premature mortality and the first large-scale investigation to directly compare the importance of socioeconomic circumstances as determinants of health with six major risk factors targeted in global health strategies for the reduction of premature mortality. Based on their findings, the authors suggested that socioeconomic adversity be included as a modifiable risk factor in local and global health strategies, policies, and health-risk surveillance.

A stratified analysis of a cross-sectional survey in urban clinics of twelve low- and middle-income countries (N=2198) showed significantly worse antihypertensive medication adherence in low-income countries (based on wealth index) (p<0.001) compared to middle income countries.[18] Demographics, treatment, clinical data and self-reported adherence questionnaire were collected by physicians. Factors associated with low adherence were investigated using logistic regression with a random effect on countries. Overall, 678 (30.8%), 738 (33.6%), 782 (35.6%) participants had respectively low, medium and high adherence to antihypertensive medication. Multivariate analysis showed that the use of traditional medicine (OR: 2.28, 95% CI [1.79-2.90]) and individual wealth index (low *vs.* high wealth: OR: 1.86, 95% CI [1.35-2.56] and middle *vs.* high wealth: (OR: 1.42, 95% CI [1.11-1.81]) were significantly and independently associated with poor adherence to medication. In addition, 26.5% of the patients admitted having stopped their treatment for financial reasons, with the proportion being 4-fold higher in the lowest than highest wealth group (47.8% *vs* 11.4%) (p<0.001).[18]

Even in countries that provide publicly funded comprehensive medical coverage, cardiovascular mortality is linked to socioeconomic status. For example, in an earlier prospective cohort study of 3407 patients hospitalized for acute myocardial infarction (MI) in 53 large-volume hospitals Canada between December 1999 to February 2003, income was strongly and inversely correlated with 2-year mortality rate (crude hazard ratio for high-income *vs.* low-income tertile, 0.45 [95% CI, 0.35 to 0.57]; p<0.001). Age, past cardiovascular events, and current vascular risk factors, however, accounted for most of the income–mortality gradient after acute MI.[19]

Psychosocial factors seem to be the driving force of the relationships between socioeconomic factors and adherence.[14,16] For example, in a cross sectional study of randomly selected hypertensive patients (N=992) under a comprehensive cardiovascular health program, the associations of education, income, diabetes, obesity, physical activity, psychosocial characteristics, smoking, and alcohol abuse with blood pressure control and adherence were evaluated by multivariate logistic regression.[14] Uncontrolled blood pressure was significantly associated with low family income, high emotional-stress-depression score and sedentary life style, among other factors.

Self-efficacy theory is a commonly used behavioral theory in other chronic diseases like diabetes mellitus, depression, and heart failure. Some authors report self-efficacy as a significant and well-documented patient-related factor among patients undergoing treatment, often associated with medication adherence in hypertensive Blacks.[20-22] Hence, self-efficacy, one of the variables studied in the original study, is hereby included in this secondary analysis study.

In summary, the literature points to the important role which social economic status plays, particularly with respect to disparity in cardiovascular health morbidity and mortality. In consideration of similar relationships found between socioeconomic status and adherence in the original dissertation study, this secondary analysis of data is being conducted to describe the relationships in greater detail.

Conceptual Model

The biopsychosocial model of illness and health guided the original study.[23] The core assumption central to the biopsychosocial model is the belief that illness is not just the result of discrete pathological processes but can be meaningfully explained in terms of personal, psychological and socio-cultural factors.[24] Dr. Engel noted that the dominant biomedical model of disease management left no room within its framework for the social, psychological, and behavioral dimensions of illness. He therefore, proposed the framework as an approach which systematically considers the biological, psychological and social factors as well as their complex interactions in understanding health, illness and healthcare delivery. Whereas the traditional biomedical models of clinical medicine focus on pathophysiology and the other biological approaches to disease, the biopsychosocial approach emphasize the importance of understanding human health and illness in their fullest contexts.[25]

The adaptation to chronic illness framework, an elaboration of the Roy adaptation model for chronic illness[26] seem to fit well into this study. Long-term adherence to hypertensive treatment regimens is one of importance in a chronic disease like hypertension, especially when the disease is largely asymptomatic. Adapting to a chronic illness encompass internal and external processes that influence responses and behaviors. An individual uses conscious awareness and choice to allow for creative personal and environmental integration.[27] The goal in living with a chronic illness becomes one of recognizing the realities imposed by the illness and restructuring self and the environment amid the new realities of living with the new experience. Psychosocial factors and perception of the impact of illness are as important as physiological factors in adaptation. In the adaptation to chronic illness model, the focal stimulus is defined as the type and duration of the chronic illness; and the contextual stimuli as demographic characteristics, ability to tolerate stress, hardiness, health promotion behaviors, and participation in health education programs. The regulator and cognator subsystems are the interaction between stimuli and the perceived degree of illness or disability caused by the chronic illness. Physiologic adaptation implies the biological responses to the specific chronic illness and psychosocial adaptation is the personal responses related to self-concept, role function, and social function.[28]

Hypertension and long-term adherence to recommended treatments seem to fit into the above models. Although the disease may not manifest with obvious physiological symptoms in the earlier stages, the related complications (stroke, myocardial infarction, heart failure, kidney disease, etc.) pose physiological and psychosocial adaptation challenges.[10,11] The findings of the parent study points to the socioeconomic and psychological factors as significant determinants of adherence in the hypertensive Black/African Americans under study.[16]

METHODS

This paper presents a secondary analysis of data originally conducted[16] to determine the effects of biopsychosocial factors on adherence to a hypertension treatment regimen in persons of African descent in the United States (US). The results of that study found that the strongest relationships were between socioeconomic factors and adherence. The analysis published in this paper serves to describe that relationship in greater detail.

The procedure employed in collecting data in the original study involved a review for human subjects' protection and approval by the Adelphi University (Garden City, NY, USA) Institutional Review Board (IRB). The subjects comprised a convenience sample of individuals residing in 21 neighborhoods with a high concentration of residents of African descent, in the New York metropolitan region. Subjects were solicited by the researcher for participation in the study at a number of free blood pressure screening fairs and through flyers at local houses of worship and libraries. The study's recruitment criteria specified individuals of African descent and a history of hypertension treatment. The data was collected through self-administered questionnaires without personal identifiers in order facilitate confidentiality. Those that participated received a $5 gift card to a well-known coffee shop chain.

Sample Size Estimation

To determine the necessary sample size for a correlation test with power of 0.80, alpha of 0.05, a medium effect size, and a two-tailed analysis, a minimum of 89 subjects was calculated.[29]

Measurement Tools

The outcome variables were measured using two scales. The first is the hill-bone compliance to high blood pressure therapy scale (HBCHBPTS).[30] The original scale consisted of 14 items. For the purpose of this study, a modified 10-item, 4-point Likert scale using Black, urban, hypertensive, South African outpatients, with a demonstrated reliability of Cronbach alphas between 0.74 and 0.84 was used.[31]

The second outcome variable (self-efficacy) was measured using a 13-item tool, 4-point Likert scale: medication adherence self-efficacy scale-revised (MASES-R).[32] This instrument demonstrated good reliability with Cronbach's alpha coefficients of 0.92 and 0.90 at baseline and at 3-months respectively.[32]

RESULTS

Treatment of the Data

The sample size consisted of 148 subjects. Among all the items in the questionnaire, only 12 data points were missing (age [8.1% of cases], and number of years with same healthcare provider [1.4% of cases]). In each of those cases, the mean was substituted in place of the missing value. The data was then analyzed for normality of the distributions of the HBCHBPTS and the MASES-R scales. Using a 95% confidence interval, less than 5% of the data were identified as outliers. As a result, the outliers were not removed in order to maximize the integrity of the data with respect to subjects' responses. A Shapiro-Wilk test of the HBCHBPTS and MASES-R indicated that the distributions are skewed and do not meet the criterion for normality (HBCHBPTS: mean=3.16, median=3.31, sd=0.84, skew=-0.98; MASES-R: mean=3.57, median=3.7, sd=0.40, skew=-1.6). In addition, a review of the histograms of the distributions clearly demonstrated negative skew for both scales. As a result, non-parametric tests were used for all the analyses.

Descriptive Statistics

The majority of subjects are female (70%), African American (32%), employed full-time (55%) and earn less than $40,000 per

Table 1. *Descriptive Statistics of the Sample (n=148)*

Variable	N	%
Gender		
Male	43	29.10
Female	105	70.90
Race/Ethnicity		
Black/American	48	32.40
Black/Caribbean	34	23.00
Black/African	50	33.80
Black Hispanic	2	1.40
Black/Other	6	4.10
Black Multiple	8	5.40
Work Status		
Full-Time	82	55.40
Part-Time	16	10.80
Retired	32	21.60
Freelance	0	0.00
Unemployed	18	12.20
Income/Year		
<$10,000	37	25.00
$10,001-$20,000	21	14.20
$20, 001-$40,000	25	16.90
$40,001-$80,000	33	22.30
$80,001 or more	32	21.60
Insurance Status		
Private Insurance	70	47.30
Medicare	30	20.30
Medicaid	32	21.60
No insurance	6	4.10
Multiple	10	6.80
Marital Status		
Married/Common-law	85	57.40
Separated	10	6.80
Widowed	10	6.80
Single	33	22.30
Divorced	10	6.80

year (56%). Most have proprietary insurance or Medicare (67%) and are married or live with a partner (57%). See Table 1 that summarizes the demographic statistics.

Univariate and Bivariate Analyses

TThe Mann-Whitney U and Kruskal-Wallis tests were used for univariate analyses and the spearman correlation was used for bivariate analyses. Among all the demographic variables, only 3 indicated statistical significance. Of note, no significant relationships were found with respect to insurance type or marital status.

1. Both, the HBCHBPTS and the MASES-R scores were significantly related to the number of years the subject received treatment from the same healthcare provider. The subjects indicated affiliation with their current provider for a mean of 8.9-years with a standard deviation of 6.9-years and a range from 0 to 27-years. The relationship of this variable to the HBCHBPTS indicated a small effect size with a correlation of r_s=0.16 (p=0.048), and to the MASES-R found a small-medium effect size with an r_s=2.0 (p=0.016).
2. Work status was significantly related to HBCHBPTS scores with respect to the difference between retired and unemployed subjects (KS=38.6, p=0.013 with Bonferroni adjustment; means=3.7 and 3.3, respectively). Work status was not found to be related to MASES-R scores.
3. Income level was significantly related to the MASES-R scores, but not the HBCHBPTS scores. The only difference in scores was observed between those subjects that earned less than \$10,000 per year and those that earned greater than \$80,000 per year (KS=-44.2, p=0.037, with Bonferroni adjustment; means=3.06 and 3.51, respectively). See Table 2 that depicts the relationships of the demographics to the HBCHBPTS and the MASES-R.

Table 2. *Relationships of Demographics to the HBCHBPTS1 and the MASES-R*[2]

Analysis	Independent Variables	Test	*p*-value
1	Number of years treated by same provider[1,2]	Spearman Correlation	<0.05
2	Work status[1]	Kruskal-Wallis Test	<0.05
3	Income status[2]	Kruskal-Wallis Test	<0.05
4	Insurance type	Kruskal-Wallis Test	NS
5	Marital status	Kruskal-Wallis Test	NS

DISCUSSION AND CONCLUSION

The current paper presents a secondary analysis of data originally conducted to determine the effects of Biopsychosocial factors on adherence to a hypertension treatment regimen in persons of African descent in the United States.[16] In the current paper, each of the SES variables was analyzed against adherence and self-efficacy. Self-efficacy has been shown to be an important independent as well as a mediating variable impacting adherence among hypertensive African American subjects.[15]

The focus of this paper ison socioeconomic factors, the main factors found to impact adherence among the multiple independent factors studied in the parent study. Interestingly, only years with the same provider, work status and income were found to significantly related to both adherence and self-efficacy in the current analysis. Interestingly, the only these three variables were also found to be related to adherence and self-efficacy (years with the same provider, work status and income) were also found to be related to adherence alone in the parent study. These findings are consistent with the literature. Prior authors found different factors impacting adherence to recommended antihypertensive regimens: financial reasons[18]; income and occupation[17]; and years with the same provider improved adherence to treatment.[16] The persistence of the relationships between socioeconomic factors and adherence to antihypertensive treatments seem crucial when addressing care among individual with cardiovascular high-risk populations like Blacks/African Americans.

With respect to work status, the current analysis found that being retired was associated with greater adherence, while being unemployed was related to lower adherence. This is consistent with literature. Prior authors have found unemployment as a socioeconomic factor impacting adherence.[12,17,18] In prior studies that included the young and older age groups, some authors found the trends towards the younger participants being less adherent than the older participants.[20,33] It is possible that the younger participants are less adherent due to responsibilities with work.

In the current analysis, adherence to therapy among full-time employed subjects was not significantly different than any other category of employment. This is an interesting finding since the parent study showed that participants with full-time work status had significantly less adherence scores than the retired group. It is possible that the other variables, other than employment status which were found to be related to adherence in the parent study, as well other studies in the literature, account for the difference noted in the relationships between full time work status and adherence. Such factors may include work-related stress, insurance status and income.[16,20,33] Further studies on the impact of employment status on adherence is suggested; particularly among younger hypertensive patients.

Perhaps the most interesting finding in the current analysis is that income was not found to be significantly related to adherence, but to self-efficacy. The KW statistic was negative. The subjects who earned less than 10 k had lower self-efficacy than those that earned 80 k+. This suggests that confidence in adherence to a blood pressure regimen is somehow related to income, even though actual adherence is not. These results were compared with findings from prior studies. Less income has been linked to less adherence to treatment. When considering sample size, methodology, statistical analysis and potential sample biases, the literature overwhelmingly points to strong relationships between income and adherence. The meta-analysis of 51 studies on the impact of socioeconomic status and hypertension showed an overall increased risk of hypertension among the lowest SES for all three indicators: occupation, education, income [pooled OR 1.19, 95% CI 0.96-1.48], where the associations were also significant in high-income countries.

That the results of the current analysis suggest that income was related to self-efficacy, although not to adherence point to the importance of self-efficacy as both an important determinant, as well as a mediating variable in adherence among Black/African American hypertension patients. A prior study have found that self-efficacy mediated the relationship between depressive symptoms and medication adherence[15]; another study found that self-efficacy mediated perceived weight-based discrimination and adherence among hypertensive African hypertensive patients.[21] Further studies on the mediating effect of income on adherence may be warranted.

The current study seem to strengthen the importance of considering socioeconomic factors (embedded in social determinants of health) in chronic disease management. The results of the current study add to the literature, suggesting that the primary factors which shape the health of all persons are social determinants of health (SDH) and include education, employment, income and other important variables.[34] The parent study found income and employment status to be related to adherence to antihypertensive regimens in the cardiovascular high-risk Black/African American population. Prior literature suggest similar findings, and the current analysis has further described those relationships. These are important socioeconomic variables which deserve further consideration.

The WHO framed health as a social phenomenon emphasizing health broadly as a topic of social justice. Hence, a conceptual framework for action on social determinants of health was formed. Consequently, health equity (described as the absence of unfair and avoidable or remediable differences in health among social groups), became a guiding criterion or principle in addressing health issues.[35] Over the past two decades, a large and compelling body of evidence reveals the powerful role social factors (apart from medical care) play in shaping health across health settings and populations.[36-38] The literature suggest that medical care alone does not determine health status. Rather, the effects of any given factor are contingent upon the presence of a myriad of other factors which include the social, economic, psychological, environmental, genetic, and epigenetic attributes.[38-40]

The socioeconomic differences in health are embedded in a larger problem of health disparities associated with a social disadvantage.[36] Nations with health policy frameworks which address social and behavioral determinants of health achieve better population health, less inequality, and lower costs than occurs in the United States.[36,41] Residents of nations with higher ratios of spending on social services to spending on health care services also have better health and live longer.[42] The US, however, spends far more money per capita on medical services than these nations, and less is spent on social services, accounting for the lagging behind of health indicators in the US than other counties.[43] Maslow hierarchy of needs phenomena further discusses the primary importance of considering basic needs of individuals.[44] Such considerations may place individuals in a more comfortable position to consider treatment recommendations offered by healthcare professionals.

LIMITATIONS OF THE STUDY

The findings of this study are limited by certain methodological conditions. First, the use of a convenience sample (lack of randomized selection) may have contributed to higher levels of adherence or self-efficacy than that which is typically found in the population and may be the reason for the skewed data distributions. Second, the nature of correlational studies does not permit the interpretation of causality. For example, the relationship between years of affiliation with the same provider may contribute to higher levels of adherence and self-efficacy or it could be the other way around.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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PUBLIC HEALTH
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Mini Review

Therapeutic Modalities: Best Practices to Protecting Patients from Harm During Treatment

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ABSTRACT

Healthcare providers and clinicians such as athletic trainers and physical therapists utilize therapeutic modalities to administer treatment to patients in the clinical setting. It is the responsibility of these healthcare providers to ensure the safe use of therapeutic modalities during treatment sessions, as well as effective delivery of treatment. Thermal-heat, ultrasound, cryotherapy and electro-stimulation treatments have the potential for causing harm to patients. Proper care and maintenance of modalities can minimize the risk to patients and avoid legal issues for physical therapists and athletic trainers. This article will explore some of the legal issues, case studies and reports as well as providing information on what healthcare providers can do to protect patients.

Keywords
Risk management; Negligence; Malpractice; Best practices; Injury prevention; Athletic Trainer; Physical Therapists; Accreditation.

INTRODUCTION

All healthcare facilities and professional clinicians must have the interest of the public, especially providing healthcare delivery. Institutions that provide therapeutic modality treatment should have the proper state-licensed professionals to conduct such treatment and patient care.[1,2] In addition, the healthcare provider should examine their facility to insure patients are not exposed to hazards from any of the therapeutic modalities equipment at the venue.[1-3] One way to examine their professional role is to review the basic principles of "duty of due care" and "breach of duty". Athletic Trainers (ATs) and Physical Therapists (PTs) owe a duty to a patient to provide services such as treatment of the medical condition in a professional manner. They also owe a duty to insure that the equipment used to deliver the treatment is maintained and safe to use.[1-4] A "breach of duty" occurs when there is insufficient supervision of the patient, or there is a failure to properly maintain or inspect therapeutic modalities used in patient care.[1-4]

ISSUES AND CONCERNS REGARDING MALPRACTICE

There is no sufficient data on ATs, but regarding PTs and looking at an analysis of closed claims by insurance sources, provided by certified nursing assistant (CNA) HealthPro and Healthcare Providers Service Organization (HPSO), the percentage of closed claims related to failure to monitor patients during treatment was 85.5% and with the average patient receiving $80,000 in an injury settlement. This accounted for over 5 million dollars paid out to all the patients injured from improper supervision.[5] According to the same analysis, the malfunction of equipment had the highest percentage (53%) of closed claims. In addition, the percentage of claims for failing to test the equipment (6.3%) and claims on not properly maintaining the equipment accounted for over one million dollars paid out to all patients injured from improper care and maintenance. The average patient received a settlement of between $31,000 and $85,000.[5] One study by Mun et al,[6] of 864 patients found that 94 were injured from burns delivered by hot (hydro collator) packs.[6] This study did not indicate if improper supervision or improper use or maintenance of the heating unit lead to the burns. Another case of malpractice, the PT was administering a "cupping treatment". The PT was allegedly involved in improper management over the course of treatment, failure to supervise/monitor the patient, failure to supervise/monitor the PT assistant.[7] In addition, the owner of the clinic was allegedly involved in failure to maintain a safe environment, making sure the clinical staff were qualified to administer cupping treatments. In this case, the patient suffered a burn and blistering to the area treated. The patient later developed an infection to the treated area. The patient discontinued coming to the clinic and suffered over a month with pain and discomfort. The patient settled out of court with an indemnity settlement payment greater than $25,000.[7]

In terms of risk management, healthcare professionals need to adhere to the U.S. Department of Labor-Occupational Safety and Health Administration (OSHA) which oversees all national standards to protect workers and the public consumer such as patients.[8] OSHA violations and fines for non-compliance are dependent on the specific violation and if an injury occurred. In addition, the U.S. Food and Drug Administration (FDA) has regulatory authority over various therapeutic modalities and their uses.[9] Federal laws associated with the FDA will have their own specific guidelines for compliance. Other organizations such as the Joint Commission on Accreditation of Healthcare Organizations (JCAHO)[10] oversee quality care in hospitals, clinics and other healthcare facilities, and this would include checking the calibrations of therapeutic modalities and maintenance and upkeep of electrical outlets such as Ground Fault Interrupters (GFI). In terms of education programs, The Commission on Accreditation of Athletic Training Education (CAATE)[11] and the Commission on Accreditation in Physical therapy Education (CAPTE)[12] oversee the educational standards of schools and colleges offering educational programs in physical therapy and athletic training. These organizations have standards specific to ensuring student and patient safety during the clinical instruction of students. Although independently owned clinics and sports care facilities may not be affiliated with CAATE or CAPTE programs, nor have JCAHO accreditation, they still must adhere to OSHA and FDA standards.

Here is the issue, what of those programs and institutions such as high schools, junior colleges and clinics that do not have to adhere to specific accreditation standards on GFIs compliance and modalities equipment checks and calibrations? Although all institutions must adhere to OSHA standard, there is always the possibility that GFI compliance and modalities calibrations will not be discovered until there is an injury or harm to a patient. The legal concern comes from the injury to a patient or athlete through the improper use of a therapeutic modality, OR the use of a therapeutic modality that is not operating properly. Lack of GFIs in treatment areas are another concern. Hydrotherapy areas that have both water and electricity exposure, can pose serious risks, so the annual checking of GFIs is very important. As a CAATE accredited program, we budget for this expenditure each year. Reviewing our records, we have spent between $700 to $900 for an independent technician to annually calibrate our therapeutic modalities and check all our electrical outlets/GFIs. Some institutions may see this expense as an elective budgetary item that can be cut to save funds.

Another method is to have the institutions electrician complete a work-order annually, review all GFIs, and document the results of the work order. One more important point, a qualified electrician should review the entire electrical system, especially in older buildings and check the GFIs and for plugs that are eroded.[2] The entire electrical system in the facility needs to conform to national and local codes. According to Prentice and Starkey,[2,3] not all three-pronged outlets are GFI and needs to be checked for grounding. Multiple adaptors and extension cords should not be in use, as this may pose a danger to patients.[2,3]

Please note that a qualified electrician should check any modality or any outlet that "trips" or shuts down, before returning it to service.[3] Spending funds on maintenance and upkeep will save you millions in a lawsuit should a patient/athlete be injured or electrocuted from defective therapeutic equipment.

RECOMMENDATIONS ON RISK MANAGEMENT

To avoid legal problems and lawsuits, here are some tips to remember regarding specific therapeutic modalities and GFIs.

CUPPING THERAPY

Cupping involves applying a heated or suction type cup to generate a partial vacuum that mobilizes the blood flow and promotes effective healing.[13] Cupping therapy has gained popularity and acceptance as a method of treating pain as well as sports injuries and other medical conditions.[13] Healthcare professionals should complete appropriate course work and hands-on learning towards a certification in cupping therapy. Prior to administering this treatment, explain all treatment concerns to the patient as well as determining any contraindications, skin conditions or skin sensitivity for administering the cupping therapy.[13]

DRY NEEDLING

According to the American Physical Therapy Association (APTA)[14] and their resource paper description of dry needling (DN) in clinical practice, "dry needling is a skilled intervention that uses a thin filiform needle to penetrate the skin and stimulate underlying myofascial trigger points, muscular, and connective tissues for the management of neuromuscularskeletal pain and movement impairments".[14]

Clinicians should be trained in administering this treatment technique and insuring a safe and comfortable environment. The clinician also needs to be cautious of patients who may have an allergic reaction to the metal in the needle (nickel or chromium) and may need to use silver or gold plated needles.[14] In addition; patients in their first trimester of pregnancy, patients taking anticoagulant medications or patients with local or systemic infections may need to avoid dry needling treatment.[14]

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LASER THERAPY

Low-Level Laser Therapy (LLLT) is a therapy approved by the U.S. FDA for certain medical procedures.[9] According to Starkey,[1] there is growing evidence to support the use of LLLT for treating inflammation and assist in wound healing, arthritis, fracture healing and pain reduction, as well as other medical conditions.[1] The precautions that need to be followed by the clinician is to observe caution with patients taking medications that increase sensitivity to light.[1] This would include patients taking certain antihistamines, oral contraceptives, non-steroidal anti-inflammataory drugs (NSAIDs), tetracycline, and antidepressants.[1] There are certain tattoo inks that may increase the absorption of laser injury, so patients that have body art, should be wary of such treatment. Patients may experience dizziness during the treatment and the treatment should be stopped and if needed, discontinue using LLLT for treatment.[1] It is also suggested because of the lack of evidence, that lasers should not be applied to small children with unfused epiphyseal plates.[1] Prentice[2] further lists contraindications such as not applying over suspected or known cancerous growth or tumors, or directly over the eyes. Pregnancy should also be contraindicated.[2] The US FDA regulates the use of Lasers and LLLT modalities.[9] With any new therapy or therapeutic modality, clinicians should be trained in their use.

ULTRASOUND UNITS

This independent review can discover several things that may become a concern. Items such as broken sound heads (interchangeable soundheads can be improperly inserted and the pins can be bent or broken) for your ultrasound unit could result in improper levels of heat being delivered to a treatment area. A broken sound head could also prevent the patient from receiving any ultrasound output or therapeutic benefit. A recommendation is to have dedicated soundheads and limit interchanging soundheads. This will prevent or lessen the chance of damage to the pins that insert into the ultrasound unit.

ELECTROSTIMULATION UNITS

Electrostimulation units (E-stim) are used to produce either change in pain response or muscle contraction.[1,2] In addition, there may be some chemical and ion effects on the muscle tissue.[1-3] E-stim units should be calibrated annually. In addition, during the annual review, broken lead wires and bad connections can be discovered and if needed replaced. It is important to eliminate any electro pad wires, connections or leads that could cause a shock or electrical burn. For hygiene purposes, the clinic should provide patients with their own individual adhesive lead pads. It is always good practice to examine your leads and pads and replace those pads with wires that appear frayed or broken and/or lose their adhesion.[1,2]

MOIST HEATING UNITS

Moist heating units (Hydrocullator Heat Packs) need to maintain a constant temperature between 164 °F and 170 °F (73.33 °C-77.66 °C).[1-3] Neglect of the heating unit can pose some legal issues given the aforementioned case study of 94 patients who had received burns from hot pads. If the water level is not at the proper levels, this could result in the unit running dry and becoming a fire hazard. Lower water levels also raise the temperature of the water in the unit above the recommended temperature range. Recommendation to prevent problems is to measure the temperature each day, record it and monitor both the temperature range and the water levels. Regulate the thermostat so it measures within the temperature range. If the temperature continues to be above the manufacture recommended temperature range, you may wish to consider replacing either the thermostat or the unit.

PARAFFIN BATH

Paraffin bath units should be free from dirt and debris and should be maintained at constant temperature of 118 °F to 126 °F (47.8 °C to 52.2 °C).[2-4] Specific units have an internal thermostat and as an extra precaution, check and log the temperature of the unit each day. This is especially important if you have a large volume of use. If this modality is not frequently used, it ought to be cleaned and stored.

WHIRLPOOL UNITS

Anytime you mix water and electricity, there is the possibility of danger.[1-4] GFIs need checking annually to ensure a secure ground. Any indication of shock needs to be dealt with immediately to prevent harm to a patient.[4] On the occasion a GFI "trip" and shuts off, the patient needs to be removed from the area. After resetting the GFI, the whirlpool unit restarted without the patient. Should the GFI "trip" and shut off again, the whirlpool should be placed out of service and off-limits until you can have the unit serviced to ensure a safe treatment environment.[4] Engine turbine needs to be checked for rust as well as appropriate function of the jets. Water seals exiting from the tub need checking to insure no water is leaking on the floor, since this may cause a patient to slip.

CONCLUSION

Risk management and patient safety should always be at the forefront of patient care. ATs and PTs need to review their educational preparation, treatment protocols, and treatment environments. Injuries from improper training, and improper use or maintenance of therapeutic equipment can results in burns and tissue damage to a patient. Another purpose of this article was to bring attention to the need for continued education and annual calibrations and GFI checks. This review was not inclusive of all therapeutic modalities you may have in your clinic or facility. The cost of annual calibrations and checking on electrical equipment may seem like a luxury to some clinics and athletic training facilities; however, the legal costs in a negligence lawsuit could soar into the millions.

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PUBLIC HEALTH

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Commentary

Mankind, Disease and Technology: A Cat, Mouse and Fiddle Game

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Mankind has been playing a cat and mouse game with diseases almost from the start of human civilization. Sometimes we have had a resounding victory, but sometimes disease has won, nearly wiping out populations in its path. Be it plague, polio, smallpox, cholera or acquired immunodeficiency syndrome (AIDS) all have left an indelible impression on humans. Just as in warfare, all these diseases have been controlled by essentially being one step ahead of them. Hence the fiddle or third factor has been technology, which could help us win this crucial time race.

Technology has enveloped all aspects of our life and it makes sense to make use of it in the field of health. Public health could be the greatest beneficiary, as new challenges continue to grow with climate change, resurgence of diseases as well as emergence of new ones, their spread being threatened by rapidly increasing air travel.

More specifically, the latest arms of technology in form of artificial intelligence (AI) or machine learning have thrown open new vistas for medical science. AI is the science of creating intelligent systems that help solve complex problems. Various potential applications include data analysis, fields of imaging, oncology, clinical decision support systems, drug research and software that uses AI in wearable technology such as Fitbits and smartwatches that helps to alert users after analyzing data.

One clear example of predictive analytics, is the use of complex data gathered through various means and processed using AI, being used to predict epidemic outbreaks. An example is the start-up AIME developing a software platform to predict dengue and Zika outbreaks. This then gives us the time to focus resources in places where it is needed and also contain it at the earliest, more importantly in resource constrained settings. Another use with AI is in analytics, where many of the radiology information systems (RIS) contain post-acquisition analysis modules that can spot pathology, and perform three dimensional (3D) reconstruction of standard 2D images. But caution has to be exercised with technology in healthcare, as there are unique problems unlike in any other field such as patient privacy, ethics and bias.

The National Health Service (NHS) in England is setting up a national AI laboratory to enhance care of patients and research. According to the Philips Future Health Index 2019,[1] among US healthcare professionals about 33% use AI-powered solutions in their practice or hospital, while countries like Germany (41%) and China (85%) surpass the US in the use of AI technologies among healthcare professionals. There is almost a global race among countries to gain leadership in AI and significant funding with investments running into billions of dollars in AI start-ups, with many focussed on healthcare. Hence, taking everything into consideration, even though the music from the fiddle is new, it is time to listen and embrace change, with adequate safeguards and cautious optimism.

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Review

Degradation of Plastic Materials Using Microorganisms: A Review

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ABSTRACT

Plastics are polymers of higher molecular mass of synthetic or semi-synthetic organic solids used as inputs for industries. Over the last few years, the need for biodegradable plastics has led to extended significance due to the extreme use of plastics and increasing pressure being positioned on to be had capacities for plastic waste disposal. Lack of degradability and the closing of landfill sites as well as growing water and land pollutant problems have caused the situation about plastics. Plastics are causing great difficulty in environmental problems and consequently, this desires manufacturers to synthesize materials that do not have an impact on the environment. The use of microorganisms in the surrounding to metabolize the molecular shape of plastic materials to produce an inert humus-like material and this is much less dangerous to the surroundings, furthermore, expertise their interaction and the biochemical adjustments they undergo are tremendously essential. In addition, the use of bio-active compounds coated with swelling materials ensures that once it is far mixed, with heat and moisture, they make bigger the plastics molecular structure and permit the bio-lively compounds to metabolize and neutralize the plastic. Thus, this overview article is revised to inspire and make an impact on the importance of microorganisms on biodegradation plastic substances.

Keywords
Biodegradation; Microorganisms; Plastics; Pollution; Hazard.

INTRODUCTION

Plastic is a matter that is hard to destroy and degrade once manufactured that goes in contradiction to natures rule; consequently, it creates a catastrophe for the complete world. Plastic is a broad term given to the various types of natural polymers having high molecular weight and is generally derived from distinct petrochemical merchandise. Most plastics are non-biodegradable and few are degradable but at a completely sluggish fee. Thus, plastics continue to be in nature with none deformation for a totally long time on account that they are obviously inert and proof against microbial degradation.[1,2]

Plastics are ubiquitous in modern life and their early uses date again to 1600 B.C. The exploitation of plastics started in 1839 with the discovery of vulcanized rubber and polystyrene.[3,4] The international utility of plastics is expanding at a rate of 12% per annum and approximately 140 million tons of synthetic polymers are produced globally each year. Plastics commodities are utilized in fishing nets, packaging, food industry, and the agricultural sector.[5,6]

After their usage, these packing materials are discarded in landfill principal pollutants and considered as the most important environmental problem since they are non-biodegradable under natural environmental circumstances. The accumulation of these plastic wastes created a serious threat to the environment and wildlife. The dispersal of household and industrial wastes pollutes the soil and these are mainly due to human activities.[7,8]

Animals are dying of waste plastics both by being stuck inside the waste plastic traps or by swallowing the waste plastic debris to exert catastrophic outcomes on the surroundings. Some of the plastic products motive, human health problems when you consider that they mimic the human hormone. Among these, vinyl chloride is classified as carcinogenic to humans and mammary carcinogen in animals by the International Agency for the Research on Cancer (IARC). Polyvinylchloride (PVC) is used in numerous purchaser merchandise, along with adhesives, detergents, lubricating oils, solvents, automotive plastics, plastic apparel, personal care products in addition to toys and constructing materials.[9,10]

Consequently, there was a need to design biodegradable polymers that degrade easily upon disposal through the action of living microbes. These polymeric materials are capacity resources of carbon and provide strength for microorganisms like bacteria and fungi which can be heterotrophic in nature. Recently, numerous microorganisms were reported to produce degrading enzymes that yield byproducts that are non-poisonous to nature in addition to residing organisms after decomposition. It is taken into consideration to be the safest technique of breakdown with much less poisonous aspect products and having the potentials of biogeochemical cycling of the substrate.[11,12] Hence, this review article was prepared to enlighten the role of microorganisms for biodegradation of plastic and to illustrate the burden on the natural, especially to the aquatic environment and the soil.

PLASTICS TYPE AND HAZARD OF PLASTICS

Plastics are of numerous types and categorized based on their properties and chemical shape.[13,14]

Thermal Properties

On the basis of plastic's thermal properties, plastics are further sub-divided into thermoplastics and thermosetting polymers.[13-15]

Thermoplastics: Thermoplastics are polymers that don't change with their chemical composition whilst upon heating and might undergo molding numerous times. Polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) and polytetrafluoroethylene (PTFE) are many of the most not unusual varieties of polymers. They also are known as not unusual plastics, variety from 20,000 to 500,000 atomic mass units (AMU) in molecular weight and have extraordinary numbers of repeating gadgets derived from an easy monomer unit.[3,16]

Thermosetting polymers: Thermosetting polymers, which include phenol-formaldehyde, polyurethanes, are different types of plastics that remain solid upon heating since they cannot be softened and changed. The chemical change is irreversible and consequently, these plastics are not recyclable due to the fact they have got a noticeably pass-linked structure, whereas thermoplastics are linear. The different way of plastic classification is based upon their relevance to the manufacturing technique and designing. It is classified in special parameters like electrical conductivity, durability, tensile strength, degradability, and thermal stability. The chemical properties of plastics are vital criteria for differentiating them into degradable and non-degradable polymers.[3,14,16]

Non-biodegradable plastics are also referred to as synthetic plastics and are derived from petrochemical products. These have an unusual repeat of small monomeric units with very excessive molecular weight. On the other hand, the degradable plastics are fabricated from starch and do not have very high molecular weight. These are generally getting broken down upon the interaction with ultraviolet (UV), water, enzymes and sluggish changes in pH. Bio pool is a highly-priced biodegradable plastic, comprised of polyhydroxy butyrate and available in the market.[8,17]

Hazards of Plastics

Chlorinated plastic can release harmful toxins into the soil, which may affect the groundwater environment. Methane gas, a highly powerful greenhouse gas produced for the duration of the degradation system appreciably causes international warming. In the ocean, plastic pollutants can kill marine mammals without delay through tangle in gadgets, consisting of fishing equipment, but it could also kill *via* ingestion, through being mistaken for meals.[18,19]

Studies have determined that each type of species, inclusive of zooplankton, cetaceans, seabirds, and marine turtles, easily ingest plastic and trash items which includes cigarette lighters, plastic bags, and bottle caps. Sunlight and seawater embrittle plastic and the eventual breakdown of large items makes it a polyethylene, a shape of plastic including shopping luggage, disposable bottles, and glasses, chewing gums, and toys, which is assumed to be carcinogenic. Phthalates, found in emulsions, inks, footwear, and toys among other merchandise, are related to hormonal disturbances, developmental troubles, most cancers, decreased sperm count and infertility and weakened immunity.[2,11]

Degradation of PVC for the duration of processing is dangerous for the surroundings and human animals (Murphy, 2001). Several polybrominated flame retardants are persistent, bioaccumulating and poisonous in nature and are also listed inside the Stockholm Convention on Persistent Organic Pollutants (POPs).[3,20] Among the phthalate plasticizers the most hazardous ones i.e. Benzyl butyl phthalate (BBP), di(2-Ethylhexyl)phthalate. DEHP and DBP, are categorized as poisonous and impair reproduction. BBP is also very poisonous to aquatic organisms with long-lasting outcomes. In addition, those phthalates, as well as DEP (diethyl phthalate) and DCHP (di-cyclohexyl phthalate), are being evaluated for the endocrine-disrupting properties (Figure 1).[5,21]

Figure 1. *A Grey Seal Inside a Sealed Shelter at Texel, Netherlands. The Seal Became Entangled in a Nylon Thread that had cut into the Flesh and Damaged the Spine.*[22]

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BIODEGRADATION OF PLASTICS

Plastic biodegradation is a process of changing properties such as tensile strength, color, chemical structure, shape, and the molecular weight of plastic polymers through microbial degradation. This process involves enzymatic and non-enzymatic hydrolysis of microorganisms, especially bacteria, and fungi.[22,23]

Biodegradability depends both on the origin of the polymer, and on its chemical structure and the environmental degrading conditions. The factors that have an effect on the mechanical nature of biodegradable substances are their chemical composition, production, garage and processing characters, their aging and the application conditions. Plastics are generally biodegraded aerobically in nature, anaerobically in sediments and landfills and partially aerobically in compost and soil.[24]

Aerobic Biodegradation

Aerobic biodegradation is known as aerobic respiration and is an important part of the natural reduction of contaminants in many hazardous waste sites. Aerobic microbes use oxygen as an electron acceptor and break down organic chemicals into smaller organic compounds with CO_2 and water by-products.[3,25]

Anaerobic Biodegradation

Anaerobic biodegradation is the decomposition of organic contaminants by using microorganisms with the absence of oxygen and is likewise a crucial component of the natural reduction of contaminants at dangerous waste sites. Some anaerobic bacteria use nitrate, sulfate, iron, manganese and carbon dioxide as their electron acceptors, to interrupt down organic chemicals into smaller compounds, C plastic$\rightarrow CH_4+CO_2+H_2O+$C residual+Biomass.[24]

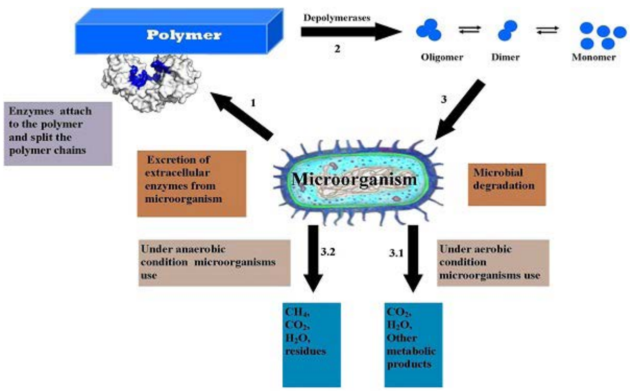
Mechanism of Biodegradation

Microorganisms are not able to move the polymers without delay through their outer cellular membranes into the cells in which most of the biochemical processes take place since polymer molecules are long and no longer water-soluble. In order to apply such substances as a carbon and strength supply, microbes evolved a method wherein they excrete extracellular enzymes that depolymerize the polymers outdoor the cells. Anaerobic and aerobic biodegradation mechanism pathways are given in Figure 2. Biodegradation of polymers entails the following steps:

1. Attachment of the microorganism to the surface of the polymer.
2. Growth of the microorganism, using the polymer as a carbon source.
3. Ultimate degradation of the polymer.[15,23]

Microorganisms are able to attach to a polymer's surface, as long as the latter is hydrophilic. Once the organism is connected to the surface, it could grow the usage of the polymer as its carbon supply. In the number one degradation level, the extracellular enzymes secreted *via* the organism inflicting the primary chain to cleave, leading to the formation of low-molecular-weight fragments, like oligomers, dimers or monomers. These low molecular weight compounds are further utilized by the microbes as carbon and electricity assets. Small oligomers might also diffuse into the organism and get assimilated in its inner environment.[26,27]

Figure 2. *General Mechanism of Plastic Biodegradation Under Aerobic and Anaerobic Conditions.*[23]



Bacterial and Fungi Species Involved in Biodegradation

There are many microorganisms (especially of bacterial and fungal origin) that have a mechanism to degrade large and complicated hydrocarbons into simpler biomolecules. They are in particular Gram-positive and Gram-negative as well as a few species of fungal origin like *Aspergillus*. Other species of microbes like *Streptococcus, Staphylococcus, Micrococcus* (*Gram-negative*), *Moraxella* and *Pseudomonas* (*Gram-positive*) and species of fungi (*Aspergillus glaucus* and *Aspergillus niger*) are worried in biodegradation system. In addition, *Bacillus megaterium, Ralstonia eutropha, Azotobacter, Halomonas* species are involved in the breakdown method (Table 1).[28,29]

Factor Affecting Biodegradation of Plastics

Biodegradation is governed by means of different factors that consist of polymer characteristics, type of organism and nature of pretreatment. The polymer characteristics along with its mobility, crystallinity, molecular weight, the sort of purposeful business and substituents present in its structure and plasticizers or components delivered to the polymer all play a vital role in its degradation.[23,34]

Chemical and physical homes of plastics play a crucial role in their biodegradation. Sidechain owning polymers are tough to degrade while in comparison to polymers without side chains. It needs to also be saved in thoughts that polymers with excessive molecular weight are difficult to degrade. The other factors worried within the biodegradation of polymers are their morphology, melting temperature and degree of crystallinity. If the polymer is amorphous, then it will be degraded without difficulty as compared to crystalline polymer. Polymers with excessive melting temperatures are hard to biodegrade. Thus, if biodegradation of plastics is to be executed at the industrial level, all these factors must be kept in mind.[28]

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Table 1. *List of Some Microorganisms*

Sources	Enzyme	Microorganisms	Plastics	Reference
Bacteria	Lipase	*Clostridium botulinum*	PCL	2,30
	Unidentified	*Firmicutes (Phylum)*	PHB, PCL, and PBS	2
	Serine hydrolase	*Pseudomonas stutzeri*	PEA, PBS, and PCL	5
	Unidentified	*Brevibacillus borstelensis*	PHA	31
	Unidentified	*Pseudomonas fluorescens* *Pseudomonas putida* *Ochrobactrum (Genus)*	PET	32,33
	Unknown	*Streptomyces (Genus)*	PHB, PVC	2
	Manganese peroxidase	*Amycolatopsis species*	PLA, PE	5
	Glycosidase	*Aspergillus flavus*	PCL	2
Fungi	Unidentified	*Penicillium funiculosum*	PHB	
	Catalase, protease	*Aspergillus niger*	PCL	
	Lipase	*Rhizopus arrizus*	PEA, PBS, and PCL	
		Rhizopus delemar	PCL	
	Cutinase	*Fusarium (Genus)*	PCL	5

PCL-Polycaprolactone, PHB- Polyhydroxybutyrate, PLA- Polylactic Acid, PE-Polyethylene, PVC- Polyvinyl chloride, PET- polyethylene terephthalate, PEA-Polyesteracetals, PBS-Polybutylene succinate, PHA-Polyhydroxyalkanoates

The biodegradability of a polymer is essentially determined by the following 8 physical and chemical characteristics:

1. The availability of functional groups that increase hydropho bicity (hydrophilic degradation is faster than hydrophobic).
2. The molecular weight and density of the polymer (lower degrades faster than higher).
3. The morphology of polymer plastic that depends on the amount of crystalline and amorphous regions (amorphous degrades faster than crystalline).
4. Structural complexity, such as linearity or the presence of branching in the polymer.
5. Presence of easily breakable bonds such as ester or amide bonds. Chain coupling (ester>ether>amide>urethane).
6. Molecular composition (blend).
7. The nature and physical form of the polymer (e.g., films, pellets, powder or fibers).
8. Hardness (Tg) (soft polymers degrade faster than hard ones).[3,13,15]

BIODEGRADATION OF NATURAL PLASTICS

Bioplastics are a special type of biomaterial. They are polyesters produced by different microorganisms and cultured under different nutrient and environmental conditions. These polymers, usually lipid in nature, are accumulated as storage materials and allowing microbial survival under stress conditions. The number and size of the granules, the monomer composition, macromolecular structure, and physicochemical properties vary widely, depending on the producer organism.[5,35]

Biodegradation of Polyhydroxyalkanoates, PHB & PHBV

Microorganisms that produce and store PHA under nutrient-limited conditions may degrade and metabolize it when the limitation is removed. However, the ability to store PHA does not necessarily guarantee the ability to degrade it in the environment. Individual polymers are much too large to be transported directly across the bacterial cell wall. Therefore, bacteria must have evolved extracellular hydrolases capable of converting the polymers into corresponding hydroxyl acid monomers. The product of PHB hydrolysis is R-3-hydroxybutyric acid,[3,36] while extracellular degradation of PHBV yields both 3-hydroxybutyrate and 3-hydroxy valerate. In general, no harmful intermediates or by-products are generated during PHA degradation. In fact, 3-hydroxybutyrate is found in all higher animals as blood plasma. For this reason, PHAs have been considered for medical applications, including long-term controlled drug release, surgical pins, sutures, and bone and blood vessel replacement.[5,37,38]

BIODEGRADATION OF SYNTHETIC PLASTIC

The primary mechanism for the biodegradation of high-molecular-weight polymer is the oxidation or hydrolysis by an enzyme to create functional groups that improve the hydrophobicity. Physical properties such as crystallinity, orientation, and morphological properties such as surface area, affect the rate of degradation.[16,19,39]

Polyethylene (PE)

Polyethylene is a stable polymer that consists of long chains of ethylene monomers; it cannot be degraded easily by microorganisms. However, it has been reported that lower molecular weight PE oligomers (MW=600-800) can be partially degraded by Actinobacter species. upon dispersion, while high molecular weight PE could not be degraded. Biodegradation of polyethylene is known to occur by two mechanisms: hydro-biodegradation and oxo-biodegradation.[3,8,40]

UV light acts as an activator, used at the beginning of the degradation process for the activation of an inert material such as Polyethylene. Similarly, it was also treated by exposing it to UV light and also treated with nitric acid. This pretreated polymer was then exposed to microbial treatment using Fusarium species. Asymmetrical flow field-flow fractionation (AF4) is a fractionation method that is used for the characterization of nanoparticles, polymers, and proteins. The theory for AF4 was conceived in 1986 and was established in 1987. It is a separation technique based on the theory of field flow fractionation. AF4 is a mineral salt medium containing treated plastic as a sole source of carbon and energy. An increase in the growth of fungus and some structural changes as observed by Fourier-Transform Infrared Spectroscopy (FTIR) were observed in the case of treated PE, which indicated the breakdown of the polymer chain and the presence of oxidation products of polyethylene.[41,42]

Polypropylene (PP)

Polypropylene is a thermoplastic that is commonly used for plastic moldings, stationery, folders, packaging materials, plastic tubs, non-absorbable sutures, diapers, etc. It can be degraded by exposure to ultraviolet radiation from sunlight, and it can also be oxidized at high temperatures. The possibility of degrading PP with microorganisms has also been investigated. Studies reported on biodegradation of PP, many microbial communities such as certain fungal species like Aspergillus niger and bacteria such as Pseudomonas and Vibrio have been reported to biodegrade PP. A decrease in viscosity and the formation of new groups, namely carbonyl and carboxyl, were observed during the degradation process.[15,27,43]

Polyvinyl Chloride (PVC)

Polyvinyl chloride (PVC) is a strong plastic that resists abrasion and chemicals and has low moisture absorption. Mostly, PVC is used in buildings for pipes and fittings, electrical wire insulation, floor coverings, and synthetic leather products. It is also used to make shoe soles, rigid pipes, textiles and garden hoses. There are many studies about thermal and photodegradation of PVC but they are only a few reports available on biodegradation of PVC. PVC having a low molecular weight can be exposed to biodegradation by the use of white-rot fungi.[15,17,44]

Polystyrene (PS)

Polystyrene is a synthetic plastic used in the production of disposable cups, packaging materials, in laboratory ware, in certain electronic uses. PS is used for its lightweight, stiffness and excellent thermal insulation. When it is degraded by thermal or chemical means it releases products like; styrene, benzene, toluene and acrolein.[3,9,27]

CONCLUSION AND RECOMMENDATION

Plastics are very useful in our day-to-day life to meet our desired needs. Due to its good quality, its use is increasing day by day and its degradation is becoming a great threat. In the natural environment, different kinds of microorganisms play an important role in various steps involved in the degradation of plastics. Studying the synergism between those microorganisms will give an insight for future efforts toward the biodegradation of plastic materials. The plastic materials have high-molecular-weight and have hydrophobic surfaces, making them difficult for the microorganisms to form stable biofilms and degrade them into small molecular oligomers. Various plastic-degrading methods are available, but the cheapest, eco-friendly, acceptable method is degradation using microbes. The microbe releases the extracellular enzymes to degrade the plastic with the complex enzymatic reaction, but further investigation still needed to be carried out. Utilization of molecular techniques to detect specific groups of microorganisms involved in the degradation process will allow a better understanding of the organization of the microbial community involved in the attack of materials. The characterization of efficient plastic-degrading microbes at the molecular level is still not available, so research should be focused in the field of genomics and proteomics, which could speed up the degradation.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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